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MELVILLE T. COOK, Editor

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ANCIENT RECORDS OF BIRDS FROM THE ISLAND OF ST. CROIX WITH OBSERVATIONS ON EXTINCT AND LIVING BIRDS OF PUERTO RICO

By ALEXANDER WETMORE
United States National Museum

During the summer of 1934 Dr. L. J. Korn, working under the Museum of the American Indian, Heye Foundation, of New York City, excavated a kitchen midden on St. Croix in the Virgin Islands, from which he obtained a considerable collection of bones of birds. Identification of this material has revealed 23 species of birds, including a number of records of value as the following list will show. The collection has been of particular interest in view of my earlier studies of bones from middens on this same island from excavations made by Mr. Theodoor De Booy.[1] And, further, has been of importance in connection with some of the extinct species found also on Puerto Rico. The additional information regarding these former Puerto Rican birds is of definite value in connection with the fauna of that island.

The site was at a place known as Concordia on the south coast about one and one half miles east of Southwest Cape, which marks the extreme southwestern extension of the island. The midden was located about 400 yards inland from the beach and was about 30 inches in depth. Bones of mammals, birds, turtles and fishes were found to the bottom of the deposit, with more birds at the center level than elsewhere.

As with most material of this kind the exact age of it is not certain, except that it antedates the period of discovery, since the deposits do not include objects of European origin. The bird bones are in good condition except for breakage, and are entirely free of animal matter. It is assumed that they have an antiquity of between 500 and 800 years. The assemblage gives a definite picture of the larger species in the avifauna of St. Croix before the forests and lagoons were despoiled by Caucasian intrusion.

[1] See Proc. U. S. Nat. Mus., vol. 54, 1918, pp. 513–522, pl. 82.

The material is preserved in the collections of the U. S. National Museum. Drawings illustrating certain specimens have been made for me by Mr. Sidney Prentice.

PROCELLARIIDAE

PUFFINUS LHERMINIERI Lesson. Audubon's Shearwater.

Two humeri with the extremities somewhat broken represent this species without question. Audubon's shearwater was found earlier in De Booy's material from a midden on Magen's Bay on the north coast of St. Thomas, and is known to breed on Saba Island two and one half miles south of the western end of St. Thomas. The present record is the first report of it from the island of St. Croix.

PELECANIDAE

PELECANUS OCCIDENTALIS Linnaeus. Brown Pelican.

Represented by parts of two humeri and an ulna.

SULIDAE

SULA DACTYLATRA Lesson. Blue-faced Booby.

A cranium, measuring 40 mm. in transverse diameter across the occipital region, from its size is identified without question as this species. The specimen represents the only record for the blue-faced booby from this area, and is a record of considerable importance as it indicates a greater range for the species in prehistoric times than at present. While the blue-faced booby nested formerly in the Bahamas it has not been reported from the Virgin Islands or Puerto Rico. The nearest modern colonies of which I have record are on the Alacran reefs of Yucatán, the Grenadines and Los Hermanos Islands on the coast of Venezuela.

SULA LEUCOGASTER (Boddaert). Brown Booby.

Represented by a cranium, fragmentary humeri, ulnae, coracoids, a metacarpal and a tibio-tarsus, this species is easily recognized. The tibio-tarsus is distinctly larger than in *S. piscator*. The brown booby occurs today along the shores of St. Croix and Puerto Rico.

SULA PISCATOR (Linnaeus). Red-footed Booby.

A fragmentary humerus, a metacarpal and an ulna come from this species which in general is distinguished from the brown booby

by rather definite skeletal characters. The humerus which is almost the same in size in the two, in the present species has the ridge for the insertion of the *latissimus dorsi* muscle placed farther from the upper margin of the bone than in *Sula leucogaster*. The ulna and metacarpal are more slender.

ARDEIDAE

ARDEA HERODIAS Linnaeus. Great Blue Heron.

A broken pelvis, parts of three tibio-tarsi, and a broken femur come from this species, easily distinguished from other herons by larger size.

NYCTANASSA VIOLACEA (Linnaeus). Yellow-crowned Night Heron.

This common heron is represented by fragments of five humeri and two femora.

PHOENICOPTERIDAE

PHOENICOPTERUS RUBER Linnaeus. Flamingo.

Next to De Booy's Rail this species is the most common bird in the present collection, indicating that it was of regular occurrence, and calling to mind the statement of A. E. Newton[1] that "large bands of some species of flamingo x x x x are said to have formerly visited St. Croix periodically, and even of late years a few seem to have been occasionally observed." There has been no other report of this bird until now, and these bones seem to be the only specimens extant from St. Croix. The species seems to have been considerably reduced in numbers comparatively soon after the coming of white men.

ANATIDAE

CHEN sp.

The proximal half of a left humerus represents a goose of this genus, agreeing in size and outline with males of *Chen hyperborea hyperborea* (Pallas). It may be noted however that in the lesser snow goose and the blue goose the head of the humerus shows no differences, so that this fragment is not identified to species. The specimen is of definite interest in that it is the first indication of these birds in the Virgin Islands. As the lesser snow goose formerly came regularly to Cuba[1] it is probable that the St. Croix bird was of that form.

[1] Ibis, 1859, pp. 365–366.
[2] Barbour, T., Mem. Nuttall Ornith. Club, 1923, p. 42.

In my account of the Birds of Porto Rico and the Virgin Islands[1] I gave uncertain records of white geese for Puerto Rico under the name of the Greater Snow Goose. It seems more probable in view of the greater range and more extended migration of the lesser snow goose that these notes properly relate to the latter form.

MARECA AMERICANA (Gmelin). Baldpate.

This duck, rare in migration in the West Indies, is represented by the distal end of a humerus. It is still found at the proper season on St. Croix as H. A. Beatty[2] records one killed on Krause Lagoon on November 11, 1921.

DAFILA BAHAMENSIS (Linnaeus). Bahama Pintail.

Several humeri and a few other bones attest the presence of this resident form.

RALLIDAE

RALLUS LONGIROSTRIS Boddaert. Clapper Rail.

Five complete tibio-tarsi and eight fragments of the same bone indicate the presence of this inhabitant of mangrove swamps. It is of interest to record that Beatty[3] records this bird as "common in the mangroves bordering Krause Lagoon, the only place on the island where they are found." This locality is on the southern part of St. Croix not far from the kitchen midden where the bones noted above were obtained.

IONORNIS MARTINICA (Linnaeus). Purple Gallinule.

The lower end of a metatarsus comes from this handsome species which has not been recorded previously from St. Croix though it is of regular occurence in Puerto Rico. The metatarsus in this species is easily distinguished from that of the Florida gallinule by the larger, deeper and more distinctly marked depression for the hallux, and by the pronounced trough-like excavation of the posterior face. Toward the head the inner margin of the bone becomes a thin plate, entirely unlike other species of its family that I have examined, except *Porphyrio,* which has the same general conformation of this bone.

[1] New York Acad. Sci., Scient. Surv. Porto Rico and Virgin Islands, vol. 9, 1927, p. 306.

[2] Journ. Dept. Agric. Porto Rico, vol. 14, July, 1930, p. 137.

[3] Journ. Dept. Agric. Porto Rico, vol. 14, July, 1930, p. 139.

NESOTROCHIS DEBOOYI Wetmore. De Booy's Rail.

The abundance of this curious rail and its importance as a food item among the St. Croix Indians is attested by the quantity of bones from the present deposit, there being remains of at least a dozen individuals and probably more. This rail and the flamingo are in fact the species most commonly represented. The rail material includes numerous femora and tibio-tarsi, several of them complete, and two humeri. One of the latter (*figs. 1–2*) is complete and shows the characters of this bone perfectly, previous specimens available having been more or less damaged. Though the humerus in all rails is relatively small, in *Nesotrochis*, when compared with other parts of the skeleton, this bone seems especially weak. The complete specimen has the following measurements: Total length 62.9, transverse breath of head 13.0, transverse of distal end 10.0, transverse breadth of shaft at center 4.2 mm. There can be no doubt that *Nesotrochis* did not have the power of active flight. The humerus mentioned is so important that drawings are given to show its characters, the specimen from Cueva San Miguel, Puerto Rico, that I have illustrated previously [1] having been defective at the lower end and on the crista superior due to corrosion from the soil in which it was preserved.

Most interesting in the present collection of bones of this species are the four specimens representing the metatarsus, which has been known previously only from a fragment, found in Puerto Rico, of the distal third of the bone. One of the present bones is complete except for slight breakage on the edge of the inner trochlea, another has the trochlea broken, and the remaining two are fragments of the head and the adjacent shaft. The complete specimen (figs. 3–7) is strong with well developed trochlea which are relatively heavy, with those at the sides less elevated above the central one than is usual in rails.

The facet for articulation of the hind toe is faintly indicated, less so than in any of the other rails examined, seeming to point to a slight and little functional development of that digit. The head is broad and strong and the shaft relatively heavy. The entire bone is decidedly reduced in length and strengthened in form when placed beside the metatarsus of such a species as *Aramides*. Following are

[1] Bull. Amer. Mus. Nat. Hist., vol. 46, May 22, 1932, figs. 8–9; New York Acad. Sci. Scient. Surv. Porto Rico and Virgin Islands, vol. 9, pt. 3, p. 34.

measurements of the complete specimen: Total length 71.5, transverse breadth of head 13.0, transverse breadth of trochlea 14.6, transverse breadth of shaft at center 5.9 mm. The broken specimen measures 13.5 mm. across the trochlea and 6 mm. across the center of the shaft. One of the fragments in only 5.4 mm. across the shaft.

The addition of the complete metatarsus to the skeletal elements of this species alters somewhat my earlier beliefs [1] as to the affinities of *Nesotrochis* among living rails. Principally from evidence obtained from the femur and tibio-tarsus I have believed it to be "a highly specialized off-shoot from the primitive stock that has produced *Aramides* and closely allied (but not ancestral) to that group of species." The metatarsus in the relative position of the trochlea and the form of the talon and adjacent parts is nearest the subfamily *Gallinulinae*. The tibio-tarsus has the head somewhat like that of *Aramides* while the distal end inclines toward the gallinules. Characters of the femur are much obscured by its heavier form so that this bone offers nothing of importance in considering relationships, while the humerus is so highly peculiar as to show no definite affinities.

After careful consideration and fresh comparisons of the additional material listed above I am led now to consider *Nesotrochis* a specialized form of the subfamily *Gallinulinae*, that so far as the New World is concerned has no close relatives. Curiously enough the modern species that I have seen whose skeleton is most similar to *Nesotrochis* is *Tribonyx mortierii* Du Bus of the distant island of Tasmania. Proportions of the lower limb are quite similar in the two species considered, though femur, tibio-tarsus and metatarsus are distinctly heavier in *Tribonyx*. The humerus is about the same in size in both. There is suggestion in these similarities not so much of close affinity as of a former wide distribution of a group of non-volant, cursorial forms of habits quite different from those of aquatic or marsh inhabiting species. While *Nesotrochis* may be now considered an aberrant member of the subfamily Gallinulinae there is suggestion that it may merit subfamily recognition when more is known of it.

It appears from information at hand even more certainly than before that De Booy's Rail was not a pond, lake or marsh frequenting bird that waded habitually in water, but instead a courser that

[1] Bull. Amer. Mus. Nat. Hist., vol. 46, 1922, p. 311.

ran over drier ground. It will be recalled that it has been found on St. Thomas, St. Croix and Puerto Rico. It is now known from the larger lower limb bones, part of the pelvis and the humerus. Additional discoveries will be awaited with interest.

LARIDAE

THALASSEUS MAXIMUS (Boddaert). Royal Tern.

An assortment of wing bones come from this common species.

ANOÜS STOLIDUS (Linnaeus). Noddy Tern.

Newton in 1859 thought that the noddy came to St. Croix but had no definite report for it. A humerus from the midden collection is the first definite record for the island.

COLUMBIDAE

COLUMBA LEUCOCEPHALUS Linnaeus. White-crowned Pigeon.

This common species is represented by an ulna and a humerus.

COLUMBA SQUAMOSA Bonnaterre. Scaled Pigeon.

An ulna, similar to that of the white-crowned pigeon but larger, is identified as this species.

ZENAIDA ZENAIDA (Bonaparte). Zenaida Dove.

This is a common species on St. Croix, of which four humeri and two ulnas have been identified. One humerus and the two ulnas are smaller than skeletons of this species at present in the National Museum collections, but the difference is considered within the range of individual variation.

Peters [1] recently has treated *Z. zenaida* as a subspecies of *Zenaida aurita*. While the two are clearly representative of the same type of dove it is my feeling that the uniform differences between them are considerable enough to warrant separation of the two groups as distinct species. I have therefore listed these bones under the name *Zenaida zenaida*. The differences between the two may be summarized as follows:

ZENAIDA ZENAIDA. Adult, grayer, paler above, below deeper reddish brown, slaty gray on abdomen and distinctly darker on under

[1] Auk, 1927, p. 535; Condor, 1934, p. 215.

tail-coverts; juvenile, paler above than adult, duller, less reddish brown, below, with under tail-coverts dark as in the adult.

Range, Bahamas and Greater Antilles (including Puerto Rico) to St. John, Tortola, Salt Island, and Virgin Gorda in the Virgin group.

ZENAIDA AURITA. Adult, darker and more rufescent above, paler below, with abdomen and under tail-coverts decidedly lighter; juvenile, darker above than adult, darker also on neck and chest but with under tail-coverts light.

Range, Saba, St. Bartholomew and St. Eustatius to Barbadoes.

Both show darker and lighter extremes due to the extent of brown in the plumage and an occasional individual of *aurita* has a considerable reddish suffusion over the abdomen and under tail-coverts, but such are separated from *zenaida* without difficulty. It is especially noteworthy that the differences between the two are as pronounced in juvenile individuals as in adults.

The Anegada Passage seems to be the dividing line in range of these two species.

I may note that earlier [1] I have listed *Zenaida aurita* from St. Croix on the basis of a record by Cory [2]. I now believe that this is erroneous and that this report by Cory refers properly to *Z. zenaida*. No other records of *aurita* have come from this island. The report of *aurita* from Virgin Gorda also I believe to be in error.

PSITTACIDAE

ARA AUTOCTHONES sp. nov.

Characters.—Tibio-tarsus similar to *Ara tricolor* Bechstein [3] but larger in transverse width; form slender when compared with larger macaws.

Type, U. S. Nat. Mus. No. 343033, left tibio-tarsus, from Concordia, southwestern St. Croix, Virgin Islands, collected in kitchen midden deposits in 1934 by Dr. L. J. Korn.

Remarks.—The left tibio-tarsus of a small macaw (figs. 8–9) is the most unexpected find in the entire collection, as there has been no previous report of such birds from St. Croix. The specimen is from

[1] Scient. Surv. Porto Rico and Virgin Islands, vol. 9, 1927, p. 398.
[2] Auk, 1891, p. 48.
[3] *A [ra] tricolor* Bechstein, Allg. Ueb. Vög., vol. 4, pt. 1, 1811, p. 64, pl. 1.

an individual that, while fully grown, was still immature as the bone is slightly spongy about the extremities. In size it is intermediate between such large species as *Ara macao* and *A. militaris* and the small *A. severa*. Its slender proportions and the more elongated ridges about the proximal end serve to show that it is truly a macaw and not an Amazon parrot like the large *Amazona imperialis*.

When compared with the tibio-tarsus of living macaws it is marked by slender form and a slightly greater posterior development of the proximal end. Aside from this its only peculiarity seems to rest in its dimensions which do not fall within those of any other species known.

It measures as follows: Total length 77.7, transverse breath across distal end 9.4, smallest transverse diameter of shaft 3.9 mm.

In the following list there are given the forms of macaws that have been recorded from the West Indies, with their distribution:

Ara tricolor Bechstein. Cuba, Isle of Pines.
Ara gossei Rothschild. Jamaica.
Ara erythrocephala Rothschild. Jamaica.
Ara sp. Haiti.
Ara guadeloupensis Clark. Guadeloupe, Martinique.
Ara martinica (Rothschild). Martinique.
Ara atwoodi Clark. Dominica.
Ara erythrura Rothschild. One of the West Indian Islands.
Anadorhynchus purpurascens Rothschild. Guadeloupe.

It is obvious that the relationship of the bird from St. Croix to any of the above is difficult to establish. There is only one, *Ara tricolor*, of which specimens are extant, the rest having been described or recorded on the basis of indefinite, uncertain and incomplete accounts of early travelers.

The tibio-tarsus from St. Croix is from a slightly larger bird than the Cuban macaw as shown by comparison with the lower end of the tibiotarsus in two skins of *Ara tricolor* in the National Museum collections. Further than this there is little that may be said about it except that it has the peculiar value of being the only specimen now known of any other species of the group from the West Indies, and that it is the only record for the region from which it comes, the nearest report for a macaw to the west being from Haiti, (none being known from Puerto Rico), and from the east and south from

Guadeloupe. While many uncertainties accompany the bone from St. Croix, particularly its affinity with the forms that have been described from the accounts of early travellers, it has seemed best to designate it by name rather than to leave it without such identification.

STRIGIDAE

GYMNASIO NUDIPES NEWTONI (Lawrence). Newton's Owl.

Two femora, one complete and one broken tibio-tarsus, and part of a humerus come from at least two individuals. Identification to subspecies is made on geographic grounds as these bones do not differ from a skeleton of *G. n. nudipes* from Puerto Rico.

CORVIDAE

CORVUS LEUCOGNAPHALUS Daudin. Puerto Rican Crow.

With eight more or less complete humeri and other bones of this crow in the present collection its former abundance in St. Croix is established, especially since this is the third site on the island from which bones of these birds have been obtained. De Booy secured it near the mouth of Salt River, and Mrs. Hugo Hark has forwarded specimens from a midden on the Richmond Estate near Christiansted. There can be no reasonable doubt that it was native on St. Croix and that it ranged the primitive forests of that island in some numbers. That it was a resident is rendered more certain by the fact that a number of the bones are from young birds that had either come from the nest or were only recently on the wing.

CORVUS PUMILIS Wetmore. Lesser Puerto Rican Crow.

This extinct crow, described from an ulna obtained in a cave deposit near Morovís, Puerto Rico, has been known until now only from the type specimen. It is of great interest to report a complete tibio-tarsus (figs. 10–12) from St. Croix that, on the basis of analogy in size, must be ascribed to this species, thus affording at one and the same time information on an additional skeletal element, and an extension of range to another island.

One of the principal characters in distinguishing *Corvus pumilis* has been size, the ulna being distinctly smaller than that of *C. leucognaphalus* and slightly larger than that of *C. palmarum*. This same degree of difference is found in the tibio-tarsus from St. Croix.

In three skeletons of *leucognaphalus* from Hispaniola the length of the tibio-tarsus varies from 82.8 to 85.1 mm. In seven *palmarum* from the same island this bone ranges from 71.9 to 77.4 mm. The specimen from St. Croix measures 78.1 mm. and as it carries about the same proportion of greater size as the ulna it is considered to be *pumilis*. It is appreciably heavier in shaft and extremities than the largest *palmarum* at hand so that there is no difficulty in separating it from that species.

Remembering that two forms of crow, one large and one small, range today in Cuba and Hispaniola, and that the finding of the extinct *pumilis* in Puerto Rico gave similar representation for that island, it is quite natural to discover the same combination on St. Croix. While *pumilis* is near *palmarum* additional skeletal material of both indicates that they are distinct.

The present find adds another interesting species to the avifauna of St. Croix.

Explanation of Plate

Figs. 1–2.—Right humerus of De Booy's Rail, *Nesotrochis debooyi*, about natural size.

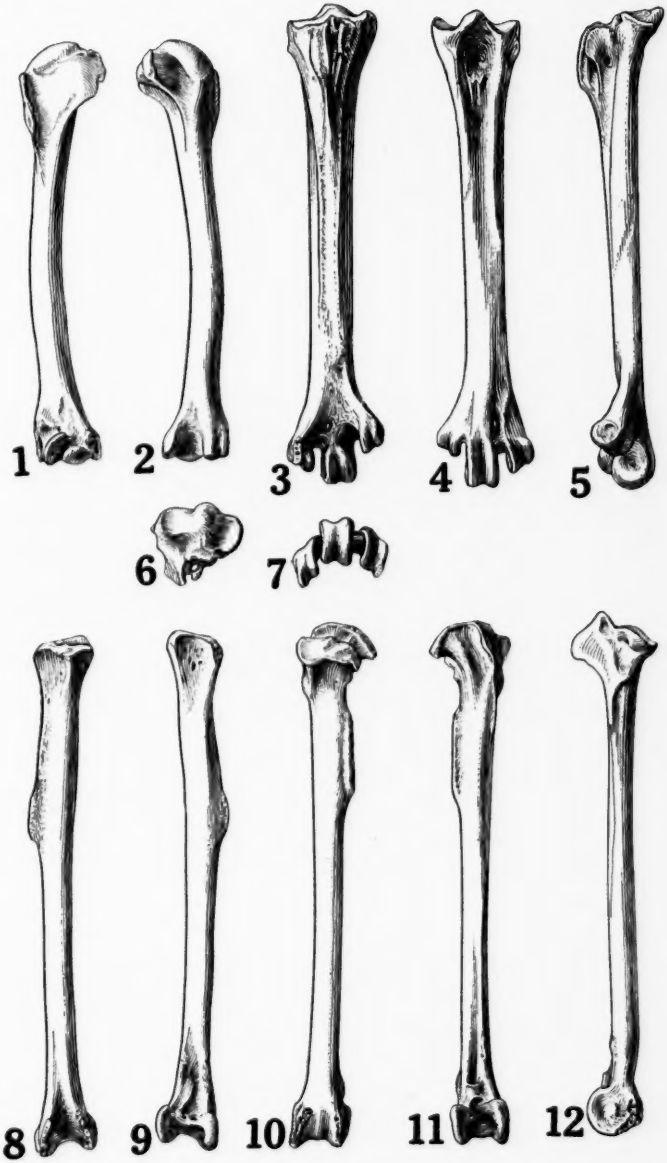
Figs. 3–5.—Left metatarsus of De Booy's Rail, *Nesotrochis debooyi*, about natural size.

Figs. 6–7.—Outline of head and trochleae of metatarsus of De Booy's Rail, *Nesotrochis debooyi*, about natural size.

Figs. 8–9.—Left tibio-tarsus of St. Croix macaw, *Ara autocthones*, about natural size.

Figs. 10–12.—Right tibio-tarsus of Lesser Puerto Rican Crow, *Corvus pumilis*, about natural size.

PLATE I



STUDIES OF THE NESTING ACTIVITIES OF LATIMER'S VIREO (*VIREO LATIMERI* BAIRD)

By NINA G. SPAULDING

The observations included in this paper were made at Algarrobo, which is situated about half way between Vega Baja and Manatí on the north coast of Puerto Rico. Here, a sandy, brush-covered coastal plain which includes Laguna Tortuguera and varies in width from about three to five miles, is abruptly terminated on the south by a series of steep, rugged, limestone hills. East and west the plain extends unbroken for miles.

This study was made on a five-hundred acre *finca* extending from the shore of Laguna Tortuguera, across the coastal plain, back into the first outeropping of limestone hills. Only a small percentage of this acreage was under cultivation. The remainder was overgrown with a low growth of scrub and brush. In sections, especially over certain parts of the coastal plain and in poorly kept pasture lands the growth was sparse. Other sections, including the hills were so densely wooded and tangled with vines that a path had to be cut in order to penetrate them. There were many small trails throughout the *finca*. It was the exact type of country favored by the species under consideration. A particularly attractive locality was a brushy pasture through which meandered a sluggish brook, bordered by a low growth of shrubs and trees.

The study in hand covers a period of three seasons, the first in 1927, from March 2 to June 20; the second, in 1930, from April 1 to May 27; the third in 1931, from January 27 to June 20.

Song.—The song of this species is exceedingly sprightly and vivacious. It usually consists of four syllables two of which are strongly accented. The accent most commonly falls on either the first and last or second and last syllables, as *moó-cha-che-píb; pa wé pa chú.* Sometimes only one accent occurs, as *pa-chibby-chú.* Syllables are occasionally increased in number, as *cha-icha-reécha-roók,* and sometimes decreased, as, *wé-pa-yoú.* One couplet may be sung at intervals of from one to three seconds and for a period of several minutes and then change to a different couplet and continue in the same manner. On February 10, for a period of two hours, a bird,

presumably a male, sang on an average of every 4 minutes and 16 seconds. Song activity occurs with the greatest frequency and vivacity from the time the male first acquires his territory, through courtship to about the middle of the nest construction period. From that time frequency and vivacity gradually wane, but it is the custom of the male to sing throughout the breeding cycle. The female sings also, but her singing is restricted to the courting season and in some individuals continues while nest building is in progress. One supposed female was noted constructing a nest (with her mate), who never uttered a note. When the female is in song, singing occurs responsively between the pair. At times responses follow so rapidly that at the climax, both birds are singing at once a most lively medley of all the varying couplets in their repertoire. Such an exhibition sometimes lasts unbroken for 20 minutes. One such was noted as early as February 26. This was during courtship. Another courtship display, sex undetermined, was the utterance of a rattle-like note, *chur-chur-chur-r-r-r* given loudly and sprightly with increasing rapidity, in response to a couplet sung by the mate. This species also has a love warble. It occurs so rarely that one is fortunate to hear it. One such exhibition consisted of one syllable uttered rapidly on the same pitch, with increasing rapidity, and finally terminating in a deliciously sweet-toned but almost inaudible series of liquid notes.

Responsive singing not only occurs between the two sexes, but also between two males (supposedly) in adjoining territories. When a mate enters the territory of another bird a lively duet ensues, and the intruding bird soon departs. One such event was noted when a pair were feeding near a nest they were building. One of the mated pair took no part in the singing.

Call Notes.—These were of three types: a grating, hoarse, cat-like mew; watchman's rattle-like *churr-r-r-r-rrr,* sometimes increasing in rapidity and accent, then diminishing and descending at the end, used at times as a scold note and at times in courtship, as has been stated, and *tup tup* often used as a conversational note by a pair when busy gleaning insects or nesting material together.

Territory.—This species has a well-defined territory, most easily determined preceding the time that the male acquires a mate. His voice is then heard daily within certain limited confines, beyond which he never seems to go. The nest is most frequently built on one of

its borders, and the rest is used as a feeding ground. In one instance the nest was placed in a line of trees and brush, beside which was a foot trail. Beyond that lay the feeding ground. It was quite densely covered with icaco *(Chrysobalanus icaco* L.). Territories are acquired at an early date. On my earliest arrival at the *finca* (Jan. 27), a solitary male whose activities were limited to one particular locality was noted. Day after day all day long his voice could be heard as he assiduously searched for insects within this limited area. He had chosen brushy pasture land, through which ran a sluggish, brush-bordered brook. Another male which had chosen for his territory a jungle-tangled hillside had a mate upon my first record of him (Feb. 3).

Nest.—The nest is cup-shaped and pendant. It is supported between two forked or parallel twigs, and is situated 3½ to 8 feet above the ground. It almost invariably overhangs an open space in the midst of a thicket, or else is found in a shrub or tree in a wind-break, bordering an open field, or in a border line of brush on the edge of a woods.

It is composed of 3 layers, the outer or camouflage, the foundation layer and the lining. The camouflage layer consists of bits of green moss, tan colored plant known and white spider egg sacs. This layer is unevenly distributed. Stems of Spanish or Florida moss (*Tillandsia usneoides* L) with the outside removed by decay, compose the foundation layer. The lining is a scanty layer of wiry, dried grass. Cobweb is employed to seal the nesting material over the two supporting twigs. We are indebted to Dr. Nathaniel L. Britton for identification of the Tillandsia stems, which have the appearance of black horsehair. When completed, the nest is a dainty, transparent affair and is so fragile that the incubating bird can be partially seen through the nest wall. Dimensions in inches average:

	Outside	Inside
Length	2½	2⅜
Width	2	1½
Depth	2¼	2⅛

The height of the nest-building season is in the early part of May. One nest observed was begun on the second of that month. Many completed nests are found by the 15th. My latest record for the beginning of nest building occurred on May 16. March 20 is my earliest record.

In the one case of entire nest construction which I had an opportunity to observe, the pair spent 10 days to the laying of the first egg, though the nest was practically finished in 6 days. Both birds shared in its construction until the afternoon of the 5th day, when the female, apparently, did all the work. The male continued to sing but no response came from the busy female. However, the male was a close attendant to his mate, hovered in the vicinity of the nest while the female was away searching for nesting material. Upon her arrival at the nest, he would sing in the bushes close by.

At the beginning of the nest, *Tillandsia* stems were dropped loosely over the two twigs from which the birds had chosen to suspend it. Later in the day, spider egg sacs were dropped into the dangling stems. Only three caught in its meshes. About 4 P. M., a loose combination of the pendant stems was effected, when twice one of the pair slipped between the supporting twigs, and by kicking and squirming matted and interweaved them to form the base of the nest.

During the second morning, the material brought consisted of spider egg sacs and two deposits of *Tillandsia*. At 12 M., the first load of plant down was brought. *Tillandsia* stems still dangled loosely.

By the 5th day the nest had been wholly closed beneath. Moss had been added and kicked through the matted *Tillandsia* stems to the outside. With the exception of one *Tillandsia* stem, moss continued to be the only material added that morning. In the afternoon, 4 loads of wiry, dried grass, 1 of *Tillandsia*, 2 of cobweb and 2 of plant down were deposited in the order given. The plant down was nestled through to the outside where it appeared with the green moss and spider egg sacs in the outer layer. Dried grass was the only material added on the 6th day. In the morning 10 loads were brought, averaging one every 17½ minutes. In the afternoon only 3 visits were paid to the nest, averaging one every 48 minutes. No song was uttered by the worker, indicating it to be the female. Singing by the male had markedly decreased, averaging one period every 18 minutes. Once, one of the pair uttered the love warble, sex unknown, but presumably, the male.

No nesting material was added after the 6th day to my knowledge. Stealthiness of movements increased. Singing by the female had ceased entirely by the 10th day, when the first and only egg was laid. The pair deserted the nest on the 12th day.

DATA REGARDING NESTS OBSERVED

Nest	Outside depth	Inside depth	Outside diameter	Inside diameter	Altitude	Tree	Time observed
1..	2¼″	2 ″	2⅝″×2½″	2½″×2 ″	8 ft.	Guamá (*Inga laurina.* Willd)	24 h
2..	1¾″	1½″	2¾″×2 ″	2½″×1½″	4 ft. 8 ″	Rama Menuda (*Myrcia splendens* Sw.) DC	1½ h
3..	2 ″	.....	2½″×2 ″	.....	5 ft. 8 ″	Pomarrosa (*Eugenia jambos L*) Br.....	5 h
4..	.....	.....	2½″×2 ″	.....	10 ft.	(*Tuonobo Stahlii. Kr & Urb.*) Britton...	0 h
5..	2 ″	.....	2½″×2 ″	.....	4 ft. 8 ″	(*Tuonobo Stahlii. Kr & Urb.*) Britton...	2¼ h
6..	2 ″	1¾″	2¾″×2 ″	2½″×1½″	3 ft. 7 ″	(*Tuonobo Stahlii. Kr & Urb.*) Britton...	1 h
7..	.....	.....	.....	.....	.....	(*Tuonobo Stahlii. Kr & Urb.*) Britton...	0 h
8..	.....	.....	.....	.....	.....	(*Miconia Thomasiana*) DC.....	1 h
9..	.....	.....	.....	.....	.....	(*Miconia Thomasiana*) DC.....	½ h
10..	.....	.....	.....	.....	6 ft. 4 ″	Pomarrosa (*Eugenia jambos L*) Br.....	6½ h
11..	2¼″	2¼″	2⅛″×1¾″	2⅛″×1⅜″	.....	Icaco (*Chrysobalanus icaco L*).....	2½ h
12..	2¾″	2½″	2½″×2¼″	.....	.....	(*Miconia Thomasiana*) DC. Britton.....	10 h
13..	.....	.....	2½″×2⅜″	.....	.....	Palo de María (*Calophyllum antillanum*)	3⅜ h
14..	2¾″	2¾″	2½″×2⅜″	.....	5 ft. 9½″	Roble Blanco (*Tabebuia pallida*) Miers..	20⅛ h
15..	.....	.....	.....	.....	.....	Aceituna Blanca (*Symplocos martinicensis*) Jacq.	0 h
Av.	2¼″	2⅛″	2½″×2 ″	2⅛″×1½″			

Eggs.—In life, the eggs are suffused with a roseate hue and are spotted with minute dots of reddish brown. A variation occurs in the size and number of these spots from a very sparse sprinkling to a considerable number. In most cases a wreath of more or less coalesced spots occurs around the larger end. In some instances these spots are a dark seal brown, including a few of pale lavender. The wreath is almost wholly absent when dots over the entire egg are sparse.

In one nest, two eggs that were laid before desertion, measured exactly alike: 20 mm × 13.2 mm. In another similar case, the two eggs measured: 19.5 mm × 14 mm. In still another instance, one egg, each in two different nests (one found on May 10 and the other on June 18 measured 3/4 inch × 9/16 inch. The height of the season for egg-laying is from the 10th of May to the 14th of June. The usual number in a clutch is 3, though one nest found in the process of incubation contained only 2 eggs. Earliest record of eggs laid: April 8 and 9. Latest: June 18.

Incubation.—A nest located on the 9th of June, 1930, offered the only opportunity for protracted observations on the incubating habits of this species. There were 3 eggs, which proved to be within 5 days of hatching. Incubation was shared by both sexes, but unequally, as one of the pair, which did not sing (supposed to be the female), averaged almost twice as much time on the nest as the singer (supposed to be the male).

The male sang when not on duty at the nest, but his voice was less vibrant and more casual than during the courting and nest-constructing periods, and was heard at rarer intervals. For these reasons and for the fact that no singing occurred when the male was incubating, it was difficult to locate nests after the beginning of this period. When he left the nest, it was his custom to sing at once from a near-by twig. There were a few exceptions when he omitted his song in the immediate environs of the nest, but instead, flew in silence across the foot-trail that separated the nesting tree locality from his feeding territory. His time was divided between these two sections. He seemed to like to hover in the vicinity of his nest and spent his time flitting from bush to bush, searching for insects, occasionally singing and sometimes preening.

Since the female did not sing when freed from incubating duties, it was not possible to follow her movements. She was never seen near the nest; in fact, she kept herself completely invisible.

The habits of the pair when covering the eggs, varied. The female almost invariably faced the fork in the branch from which the nest was suspended, while the male assumed a position at right angles to his mate, with bill propped against one of the supporting nest twigs and his tail against the other. The female was more alert and nervous. She moved her head frequently and sometimes completely changed her position. His movements were less frequent. At times when the male sang on a twig close to the nest, the female would become very alert, reach up her head and peer between the leaves as if to see him. Her behavior at such a time indicated his intentions. If he were ready to relieve her, she would look in all directions to see if it were safe for her to leave the nest, and then creep to the rim and drop out of sight. If he failed to approach, she would quietly settle back in the nest. If any other species of bird invaded her immediate vicinity, she was startled. The flapping wings of a Mocking Bird, and the sharp *tink* of a Bryant's Grassquit in the shrubbery close by would cause her to raise her head instantly and look all about.

The method of approach and departure from the nest was quite similar on the part of both birds. The approaching bird customarily alighted on the rim of the nest, or on a twig just above it. Usually the departure was slow and cautious up to the final dash, but there were exceptions when the exchange was made swiftly.

I did not see the male turn the eggs. In the morning on the day before the eggs hatched the female turned them at 11.50, 12, 12.09,

12.13, and 12.20; in the afternoon, at 5.12, 5.15, 5.34, 5.40, 6.05, and 6.13. At 5.50 she appeared to be turning the eggs, but when she raised her head she seemed to be eating something. I concluded she was cleaning the nest. At 6.26, this act was repeated. When turning the eggs, she sometimes accomplished it by tucking her head under her breast, and sometimes by standing and backing up against the side of the nest, then reaching down and moving the eggs with her bill. The nest wall was so thin that the bird was visible through it as she worked inside. Frequently she snuggled and cuddled as she settled over the eggs. Observations were made on this day from 10.40 A. M. to 1.06 P. M. and from 3 to 6.48 P. M. That night, before leaving, I flushed the incubating bird to see if the eggs had hatched. The bird permitted me to lower the branch before making her escape and offered no resistance.

On the day preceding the hatching of the eggs a more cautious behavior was noted on the part of both birds. For the first time they appeared conscious of my presence. This was seen by the manner of approach to the nest. They would come creeping along a twig behind the leaves to the nest and pause. The setting bird would fly or drop down out of sight, and the other would instantly slip inside the nest. I made observations from 9.53 to 12.18 that morning. Eggs were turned but once, and that by the female at 10.02. While the female incubated for 86 minutes the male spent 57 minutes near the nest and only 29 minutes across the trail.

The length of the incubating period remains undetermined. The height of the season occurs from about the 10th of May to the middle of June. Earliest record of an incubating pair: May 12; latest: June 9. Incubation was shared by both sexes, but unequally, as the female covered the eggs nearly twice as long as the male.

Rearing of Young.—The report which follows was obtained from observations of two nests, one of which was that of the incubating birds just described. The 3 eggs were found hatched on June 14. Observations were continued for three days. In the other, 2 eggs hatched on May 23, and the third on the 24th.

The height of the season occurs from about the 20th of May to the latter part of June.

Both parents shared in the parental duties of brooding and feeding, with the male feeding about four times as often as the female, and the female brooding about twice as much as the male. The young were closely brooded during the four days of observation, the exchange on the nest being effected at once by the pair. When

the young were left uncovered it was for periods of 5 to 8 minutes, and for this time, only once or twice during a day, for the first two days; on the third day with respect to one nest, five such occasions ocurred, with the longest period lasting 15 minutes.

Unless the female was ready to leave the nest on the arrival of the male with insects, he deposited them in her bill and she in turn mashed and fed them to the young. If she were ready to leave, she would usually fly and he would feed the young himself and remain to brood. Occasionally, the female would take a part of his load to eat, herself, before leaving the nest. Sometimes she would eat the whole load and continue brooding. The female never feeds her load of insects to the brooding male, but always directly to the young. When she arrives he departs. At times, on the approach of the male to the nest, the female repeatedly opens her bill wide and shuts it until he deposits the load in her mouth. Once the male was noted conducting himself in like manner, but she did not offer him any of her load and he flew. Both birds frequently uttered a metallic, *tsup tsup*, upon approach to the nest, evidently as a warning to the brooding bird to vacate. Insects were often mashed by both the male and female before they were given to the young. At times, after a deposit had been made in the gaping mouth of one of the young, it was withdrawn by the parent, mashed and redeposited. In one instance this was repeated 12 times before it was swallowed. On one occasion, when it was almost dusk, the male came with his last load for the day. It consisted of a larva that hung dangling from his bill, and was so big that the whole family had a meal from it. The female took it and her head disappeared into the nest. When she raised it, some of the worm was still visible in her bill. She held it out to him. He picked off a piece and ate it, and she ate the rest.

On more than one occasion the male arrived at the nest empty billed. He alighted on the twig immediately above it, and looked at his mate in the nest below him, then reached his head down toward her and eyed her slowly with one eye and then the other, with a very solicitous expression. She ignored his presence. He continued to look her up and down from head to tail and back again, but with no response. He then reached down until his bill almost touched hers. She still paid no attention. Presently, he pecked her bill three or four times. This produced no effect. He then hopped to the next twig above, looked back into the nest, crept along the twig and dropped downward. In 2 minutes he returned with an insect,

but the female did not let him brood until 19 minutes later. On another similar occasion when he touched her bill with his he poked it gently as if nudging her to make her fly and let him brood. She snapped her bill wide open and glared at him. He flew at once. Still another time he alighted on the twig just below the nest and reached his head up close to his mate's so their bills almost touched. They remained thus for 5 minutes.

Feedings averaged every 9½ minutes during the whole time observed at the nest which hatched on June 14.

Both birds attended to the cleaning of the nest. The excrement pellets were eaten.

These vireos are fearless in defense of their young. In the case of the May nest it will be recalled that two young and one unhatched egg were found in it, on the 23rd. On that day the brooding bird let me set up the camera within 2 feet of the nest. When I put my finger almost over him, he pecked at it. Not until I broke off a leaf above him, did he fly. He dashed back at once upon cessation of the disturbance. After all the eggs are hatched the behavior becomes fiercer and bolder. Upon approach to the nest to examine the young the brooding bird alighted on a near-by twig, spread his wings wide, fluttered and uttered his loud, shrieking, grating cat-like drawl, then flew at my face again and again, even daring to strike with his bill. He returned to the nest at once upon my departure. On the second day when the nest had been vacated by the parents for a few minutes, upon may approach to it, both of the pair instantly appeared in defense of the young, one flying at my head and the other bravely alighting in a bush at my feet. Upon my withdrawal, both continued their search for insects close by.

During the hottest part of the day the brooding bird would rise and stand, as if to cool the young. On one such occasion the bird remained thus for 3 minutes.

The young were naked and blind upon hatching. The general color was light reddish pink; the bill was creamy white; top of head, pale flesh color; back, reddish pink; wings the same, except for dark gray along the upper edge; chest reddish pink; belly dark gray; legs pinkish or flesh color. Wing quills began pricking through on the second day.

The young made little peeping sounds, but so faint that they were only audible when one's ear was close to the bottom of the nest.

A summary of observations on nest activities of the parents whose young hatched on June 14, follows:

	Observed	Singing							Brooding								
		No. of Periods	Average occurrence in Minutes	Total Number of Couplets	Maximum Number at a Period	Minimum Number at a Period	Maximum Time Silent	Minimum Time Silent	Number of Periods Male	Number of Periods Female	Total	Number of Minutes Male	Number of Minutes Female	Total	Average Male	Average Female	Minutes Young Unbrooded
June 14.....	8 h. 7 min.	40	12	170	18	1	48	1	8	9	17	154	306	460	18	34	
June 15.....	5 h. 38 min.	17	20	48	6	1	124	½	5	7	12	93	229	322	18	33	16
June 16.....	3 h. 37 min.	4	54	9	4	1	103	4	3	6	9	28	140	168	9	23	49
Total...	17 h. 22 min.	61	28	227	....	....	....	....	16	22	38	275	675	950	15	30	70

	Observed	Feeding						Excrement			
		Number—Male	Number—Female	Total	Average Frequency in Minutes	Longest Time Between Feedings	Shortest Time in Minutes Between Feedings	Times Eaten by Male	Times Eaten by Female	Total	Average in Minutes
June. 14.....	8 h. 7 min.	48	8	56	8	30	1	4	12	16	30
June 15.....	5 h. 38 min.	22	7	29	11	40	1	3	11	14	24
June 16.....	3 h. 37 min.	17	7	24	9	27	3	1	2	3	72
Totals.....	17 h. 22 min.	87	22	109	9	.....	.....	8	25	33	42

The low average rate of cleaning the nest on the 16th may be due to the fact that on that date observations were not made until late in the afternoon and for a shorter time than on the previous days.

Behavior of Male upon Destruction of Mate and Young.—Unfortunately, the female and young in this nest (June 14) were destroyed between 7 P. M., on the 16th and 9.30 A. M., the on 17th. Feathers of the former were clinging to leaves above the nest and some were on the ground. Two notable changes were recorded in the behavior of the male. Frequency of singing increased and he flew beyond the confines of his territory. Wherever he went he always returned to the nest environs, but was never seen immediately at the nest. When in his feeding ground he flew so far beyond that his voice was barely audible. Previously, he had never fed south of the borderline

of brush in which the nest was located. Now, he flew so far in that direction that he was out of hearing. He was gone 29 minutes, then returned to the nest vicinity, still singing. He seemed to be searching and calling in all directions for his mate and nestlings. There was no pause in his singing. *Pa chibby chú* he sang. The last syllable had an unmistakably plaintive quality. The 19th was the last day of observation. The bird was still flying far afield but never failed to return to his territory. His singing was constant, but subdued and colorless. When he flew east of the nest (a direction not included in his territory, except for a matter of a few feet), and continued so far that his voice became barely audible, I followed him and overtook him singing in a *Miconia* bush, a few feet from the trail that led back, past his nest, and there I left him.

More data is needed to determine the length of the incubating season and the time from the hatching of the young to their departure from the nest, also a more extended study of the nestlings and of other problems that arise in the mind of the observer that still remain unsolved.

Explanation of Plates

Habitat of Latimer's Vireo (*Vireo latimeri* Baird)

Fig 1.—Nest in lower branches of tall tree on left; feeding ground on right of trail.

Fig. 2.—Feeding territory, overgrown with *icaco* brush.

Fig. 3.—Nest of Latimer's Vireo (*Vireo latimeri* Baird). Shows white spider sacs at base of nest.

Fig. 4.—Eggs of Latimer's Vireo (*Vireo latimeri* Baird). Laid April 8 and 9, an exceptionally early record. Nest deserted.

Fig. 5. Brooding bird.

Fig. 6.—Bird feeding young.

Fig. 7.—Nest of Latimer's Vireo (*Vireo latimeri* Baird). Excepitonal. Outer layer of gray lichen; no spider egg sacs or moss. Never occupied.

PLATE II

PLATE III

PLATE IV

A FARM MANAGEMENT STUDY OF 224 COFFEE FARMS IN PUERTO RICO, 1934 *

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DESCRIPTION OF THE AREA STUDIED

LOCATION

The coffee farms included in this study are all located in the coffee region of Puerto Rico, which comprises practically all of the west central mountain section of the Island (figure 1).

This study is based on records of farm businesses in the municipalities of Mayagüez, Las Marías, Añasco, Moca, San Sebastián, Lares, Utuado, Adjuntas, Jayuya, Ciales, Ponce, Juana Díaz, Villalba, Guayanilla, Peñuelas, Yauco, Sabana Grande, San Germán, and Maricao (figure 2).

CLIMATE

The mean annual temperature in the coffee area of Puerto Rico ranges from 68 degrees Fahrenheit in the higher sections to 76 degrees in the sections of lower elevation.

The average yearly rainfall ranges from 60 to 120 inches. Rainfall is not evenly distributed throughout the year, thus accounting for the so-called wet and dry seasons. The wet season usually starts in May and lasts until October, while the dry season includes from November to April.

Abundance of sunshine and a continuous growing season throughout the year are characteristic of Puerto Rico, as well as of other tropical countries.

SOILS

Practically all of the soils in the area studied are of a clayey nature, generally lacking in lime and in organic matter.

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* A thesis presented to the faculty of the Graduate School of Cornell University, June 1936, in partial fulfillment of the requirements for the degree of Master of Science in Agriculture.

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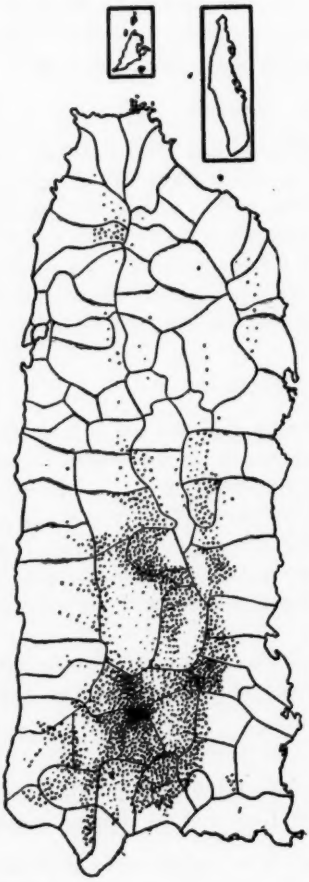

FIGURE 1. ACRES IN COFFEE IN PUERTO RICO, BY MUNICIPALITIES*
1 dot represents 100 acres.

* Puerto Rico Agricultural Experiment Station Bulletin 41, Types of Farming in Puerto Rico, p. 31. Based on U. S. Census, 1930.

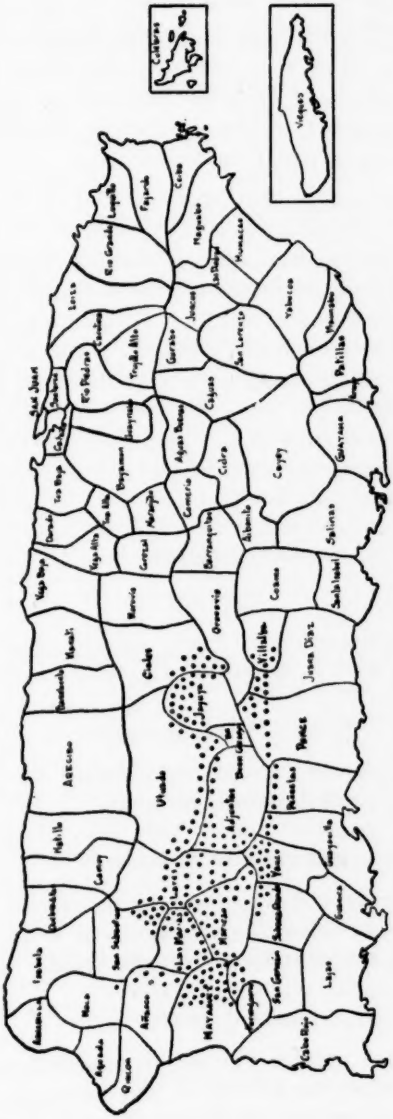

FIGURE 2. LOCATION OF THE FARMS STUDIED, BY MUNICIPALITIES

1 dot represents 1 farm.

The predominating soils in the coffee area of Puerto Rico are classified as Catalina, Frontón, Descalabrado, Utuado, Múcara, Moca, Viví and Cialito series, according to the soils survey of the Island.

TOPOGRAPHY

The elevation ranges from 500 to 2,500 feet above sea level in the area where coffee is grown in Puerto Rico.

TRANSPORTATION FACILITIES

Due mostly to the rough topography, transportation facilities are not very good. Several important insular highways run across the area, and many other gravel or dirt roads are also to be found. These, however, do not supply the entire needs for roads, and thus a large number of farms are to be found entirely off the roads, and are accessible only on horseback.

Of the 224 farms studied, 46 per cent were located on highways, 17 per cent were on gravel or dirt roads, and 37 per cent were entirely off the roads.

DEFINITIONS

CUERDA

The unit of land measure in Puerto Rico. It corresponds very closely to the acre, since it is equivalent to 0.9712 acres.

TOTAL CUERDAS IN CROPS

The total area planted to crops on a farm. Does not include permanent pasture, wooded pasture, or woods.

NET CUERDAS IN CROPS

From the total *cuerdas* in crops, subtract the *cuerdas* intercropped and double-cropped, to obtain the net *cuerdas* in crops. Represents the total area that was actually under cultivation.

ANIMAL UNIT

A measure of the average number of animals kept on a farm during a year, based on the amount of feed consumed and value of manure produced. A mature cow, bull, horse, mule, 2 heads of young stock, or 100 hens are each considered as one animal unit.

MAN EQUIVALENT

The average number of persons working on a farm during a year, reduced to an adult-male basis. It is obtained by adding the total months of labor on the farm, including 12 months for the operator, and dividing by 12.

CAPITAL INVESTED

The value of all farm property, land, houses, buildings, livestock, feed, seed, and equipment. The average of the amounts at the beginning and end of the year is considered as the capital invested in the farm business. It is also termed farm capital.

RECEIPTS

Total farm receipts or gross receipts include: 1, the amount received for all crops sold plus the value of the crops at the end of the year which were to be sold; 2, the amount received from the sale of livestock; 3, the amount received from livestock products sold; 4, the amount received from miscellaneous sources, such as work off the farm and rent of farm buildings; 5, the amount by which the farm capital at the end of the year exceeded that at the beginning.

EXPENSES

Include all farm business expenses. In order to put all farms on a comparable basis, the value of the unpaid family labor, except that of the operator himself, was charged as an expense at what it would have cost to hire the work done. Value of livestock purchases, of new equipment or buildings, and repair of buildings and equipment were also included as expenses. When the farm capital at the end of the year was less than that at the beginning, this decrease in inventory was included as an expense. Household or personal expenses were not included.

FARM INCOME

Is the difference between total receipts and total expenses on a farm during a year. It represents what the farmer received for his year's work and for the use of all the capital invested in the farm business.

LABOR INCOME

Is the farm income less interest at 8 per cent on the average farm capital. It is what the operator received for his year's work in addition to having a house to live in and privileges from his farm.

Labor income is not comparable to the salary of a person living in a city. It is comparable, however, to the wages of a married hired man who is given a house and farm privileges besides his cash wages.

The labor income made on a farm is one of the best measures of its efficiency.

FARM PRIVILEGES

The value of all the products, such as milk, eggs, wood, charcoal, and livestock produced for home consumption, together with the estimated rental value of the farm house, constitute the farm privileges of a farmer.

LABOR EARNINGS

To the labor income add the value of the farm privileges, and this gives the labor earnings. This figure is more nearly comparable to the salary of a married hired man working in town.

RETURN ON CAPITAL

From the farm income subtract the estimated value of the operator's labor and management, to obtain the return on capital. In estimating the value of his work, the operator was advised to base his estimate on what it would have cost him to hire the work done by himself, in addition to the farm privileges he obtained during the year.

Since farm income, as already defined, is the income from capital and operator's labor, the return on capital is obtained by subtracting the value of this labor from the farm income.

PER CENT RETURN ON CAPITAL

This is the return on capital, as given above, expressed as a percentage of the average farm capital.

It is a very good measure of profits on a corporation type of farm with a large capital investment and where the owner does not run his business himself, but hires a manager.

CROP INDEX

The yield per *cuerda* of all crops on a farm, when expressed as a percentage of some base, is the crop index on this farm. For this study, the base used was the average yields during 1934 of all the farms studied. This base was considered as 100. If, for example, a farm had a crop index of 75, this means that the yields of all the

crops on that farm, averaged together, were 75 per cent of the yields of the same crops on all the farms.

The crop index was weighted by the acreage planted to each crop. For example, if a farmer had 30 *cuerdas* of coffee, and 10 *cuerdas* of bananas, the coffee received three times as much weight in the crop index as the bananas.

Since coffee was the main crop on each of the farms included in this study, the crop index for each farm is very heavily weighted by the acreage of coffee. Hence, the crop index and the yield of coffee per *cuerda* on most farms were about the same.

LABOR COSTS PER CUERDA IN CROPS

Include the cash cost of the hired labor, together with the cost of the board furnished to this labor, divided by the net *cuerdas* in crops on each farm. The value of the operator's labor or of the unpaid family labor was not included.

CAPITAL TURNOVER

Is the number of years required for receipts to equal capital. The capital turnover of a farm is obtained by dividing the average farm capital by the total receipts.

METHOD OF PROCEDURE

The survey method was used in making this study of coffee farms in Puerto Rico. The survey blank used consisted of two parts: the economic part, on which this study is based; and the agronomic part, which covered as nearly as possible all the phases and problems of coffee farming in Puerto Rico. Each farm, after being surveyed, was thoroughly inspected by the enumerator and the farmer. The records were taken during February to April, 1935; and the information obtained refers to the calendar year 1934.

The sample consisted of 224 farms, selected at random, in the most important coffee municipalities, based on the acreage on coffee in each of these municipalities, as reported by the 1930 census. No farm was included which did not have at least 6 cuerdas of bearing coffee or which did not get a major portion of its receipts from coffee.

Office tabulation, labor-income summaries, and business analyses for each farm were made at the Department of Agricultural Economics of the University of Puerto Rico, under the supervision of the author. Further tabulations, sortings, and cross-tabulations of the data were made by the author at Cornell University.

SIZE OF FARMS AND USE OF THE LAND

The 224 farms surveyed for this study covered a total area of 41,241 *cuerdas*, of which 26,123 *cuerdas* were planted to different crops. Of these, 4,524 *cuerdas* were intercropped and 208 double cropped, leaving a total of 21,373 *cuerdas* net in crops (table 1).

Intercroppings consisted, for the most part, of banana and orange trees. Banana plants provided most of the temporary shade required by the coffee bushes. Orange trees were used to quite an extent to provide part of the permanent shade.

Double cropping is not characteristic of a coffee farm. It occurs only in those sections where tobacco is also one of the main cash crops, the land planted to tobacco being used for vegetables and minor crops after the tobacco crop has been harvested.

Wooded pasture, which occupied 19 per cent of the area, was in practically all cases land in preparation for coffee plantings. Much of this wooded pasture was planted to shade trees to replace those destroyed by the 1928 and 1932 hurricanes.

Permanent pasture accounted for 7,110 *cuerdas*, or 17 per cent of the total area. The rest of the land in these farms was devoted to woods (1,729 *cuerdas*), occupied by buildings, roads and fences (1,709 *cuerdas*), or actually waste land (1,532 *cuerdas*) entirely unfit for agriculture.

The average size of farm was 186 *cuerdas*, of which 96 *cuerdas* were devoted to crops, mostly coffee; 35 *cuerdas* to wooded pasture; 32 *cuerdas* to permanent pasture; 8 *cuerdas* to woods; 8 *cuerdas* occupied by buildings, roads and fences, and 7 *cuerdas* of waste land.

TABLE 1. SIZE OF FARMS AND USE OF THE LAND

224 COFFEE FARMS, PUERTO RICO, 1934

	Total for all farms	Average per farm	Per cent of total
	*cuerdas**	*cuerdas*	
Total in crops	26,123	117	.....
Intercropped	4,542	20	.....
Double cropped	208	1	.....
Net in crops	21,373	96	52
Permanent pasture	7,110	32	17
Wooded pasture (maleza)	7,788	35	19
Woods (monte)	1,729	8	4
In buildings, roads, and fences	1,709	8	4
Waste land	1,532	7	4
Total in farm	41,241	186	100

*The *cuerda* is the unit of land measure in Puerto Rico. Equivalent to 0.9712 acres.

FARM CAPITAL

The average farm capital for all farms studied was $15,580 (table 2). Of this, 95.8 per cent was invested in real estate, 1.8 per cent in livestock, and 2.4 per cent in equipment. The total investment per *cuerda* averaged $84.

The value of the land alone constituted 83.4 per cent of the total investment per farm, and averaged $70 per *cuerda*.

The value of the operator's house accounted for 5.2 per cent of the total investment. That of the buildings, of which houses for the "arrimados" were most important, represented 4.0 per cent of the farm capital. An "arrimado" is a hired man who is given a house to live in and usually a tract of land for a home garden. This type of hired man is characteristic of the coffee region of Puerto Rico, and may also be found in the tobacco areas, but is unusual in the sugar cane belt.

TABLE 2. FARM CAPITAL

224 COFFEE FARMS, PUERTO RICO, 1934

	Average value per farm	Per cent of total
Land	$12,997	83.4
Operator's house	808	5.2
Machinery house	388	2.5
Other buildings	629	4.0
Glacis*	104	0.7
Total real estate	$14,926	95.8
Livestock	286	1.8
Equipment	368	2.4
Total	$15,580	100.0

* Glacis is a concrete floor for drying coffee in the sunlight.

CROPS GROWN

Coffee culture in Puerto Rico is mainly a single crop type of agriculture. The acreage planted to coffee, both bearing and nonbearing, constituted 75.9 per cent of the total *cuerdas* in crops on these 224 farms in 1934 (table 3).

Bananas were second in importance as to acreage, and represented 11.7 per cent of the total *cuerdas* in crops. The banana plant constituted the most widely used type of temporary shade for coffee in Puerto Rico, because of its rapid growth, excellent shade, and its use for family consumption, hog feed, and as a source of cash income.

Citrus, especially oranges, occupied 5.2 per cent of the total *cuerdas* in crops. They were used as permanent shade, and were usually planted along the sides of the farm roads and lanes. The use of

citrus for shade has no particular advantage, besides the small income that may be derived from the crop, because of its susceptibility to certain insect and fungus pests that may also attack coffee. The present tendency of most coffee farmers is to eliminate citrus of all kinds from their coffee farms; but, as yet, the progress of this movement has been slow.

Other minor crops besides bananas, including plantains, corn, beans, yautías, and pigeon peas, together constituted 4.5 per cent of the total *cuerdas* in crops. These crops were mostly for home use.

TABLE 3. CROPS GROWN

224 COFFEE FARMS, PUERTO RICO, 1934

Crops	Total for all farms	Average per farm	Per cent of total
	Cuerdas	*Cuerdas*	
COFFEE:			
Non-bearing	8,243	36.8	31.6
Bearing	11,577	51.7	44.3
Total	19,820	88.5	75.9
CITRUS:			
Oranges	1,212	5.4	4.6
Other citrus	61	0.3	0.3
Non-bearing	58	0.3	0.3
Total	1,331	6.0	5.2
MINOR CROPS:			
Bananas	3,076	13.8	11.7
Plantains	136	0.6	0.5
Corn	345	1.5	1.3
Beans	246	1.1	0.9
Yautías	133	0.6	0.5
Pigeon peas	118	0.5	0.4
Other	207	0.9	0.9
Total	4,261	19.0	16.2
Sugar cane	192	0.9	0.8
Tobacco	302	1.3	1.1
Used by share-croppers	217	0.9	0.8
Total crops	26,123	116.6	100.0
Less: Intercrops	4,542	20.3	17.4
Double crops	208	0.9	0.8
Net cuerdas in crops	21,373	95.4	81.8

Sugar cane was the second most important cash crop on seventeen coffee farms, where the soil was especially adapted or where transportation facilities from the farm to the sugar mill were exceptionally good.

Tobacco was an important cash crop on 21 of the coffee farms. On these farms the income from this crop was a real help to the farmer, especially after the hurricanes; because, being an annual crop, it provided him with a source of income to help meet the large expenses involved in the rehabilitation of his coffee farm.

Of the total *cuerdas* in crops 17.4 per cent was intercropped. Intercropping is characteristic of the Puerto Rican coffee farms as they are today. A large percentage of the acreage in bananas and citrus was intercropped with the coffee.

Double crops were found almost exclusively in those farms which also grew tobacco, the land being planted to minor crops after the tobacco had been harvested. On these farms the system of share-croppers was also found. The area worked by share-croppers represented about 1 per cent of the total *cuerdas* in crops.

Net *cuerdas* in crops represented 81.8 per cent of the total *cuerdas* in crops or an average of about 96 *cuerdas* per farm. Of these 96 *cuerdas*, 88.5 were in coffee with bananas and citrus intercroppings. The balance was mostly in minor crops, tobacco or sugar cane.

AGE OF COFFEE BUSHES

The total *cuerdas* in coffee of all ages was 19,820 *cuerdas*. Of these, 8,243 *cuerdas*, or 42 per cent were from one to three years of age; 4,961, or 25 per cent, were from four to eight years old; and 6,616, or 33 per cent, were nine years old or more. Very few, if any, were more than twenty-five years old (table 4).

Under normal conditions in Puerto Rico, coffee bushes do not generally start to bear until after the third year. They will then bear lightly, and will reach full bearing capacity during the sixth or seventh year.

Of the area in coffee in these farms, 42 per cent was under bearing age and 58 per cent was either just starting to bear or in full bearing during 1934.

The new coffee plantings set after the 1928 hurricane would have started to bear by 1932, had it not been for a second hurricane in that year. Since this last hurricane, new plantings have been started again. This accounts for the large percentage of non-bearing coffee bushes in 1934.

TABLE 4. AGE OF COFFEE BUSHES
224 COFFEE FARMS, PUERTO RICO, 1934

Age of Coffee Bushes	Cuerdas	Per cent of total
(Years)		
1—3	8,243	42
4—8	4,961	25
9—25	6,616	33
Total	19,820	100

CROP YIELDS

During 1934, the average yield of coffee per *cuerda* on the farms studied was 92 pounds (table 5). On 26 per cent of the number of farms, the yield of coffee per *cuerda* was less than 50 pounds, while on 11 per cent of the farms, it was more than 200 pounds. The highest yield obtained on any of the farms was 378 pounds, and the lowest was 12 pounds per *cuerda* of coffee. An average of 92 pounds per *cuerda* during 1934 was only from one-half to one-third of what is generally considered a satisfactory normal yield of coffee in Puerto Rico.

Sugar-cane yield on these coffee farms averaged 492 quintals per *cuerda*. This yield of sugar cane compares satisfactorily with the average for the northern coast of Puerto Rico where sugar cane is grown, but is much lower than the average for the southern coast, where a large proportion of the sugar cane is grown under irrigation.

Most of the coffee farms where tobacco was grown, were located in the municipalities of Utuado and Jayuya, two of the leading tobacco areas in Puerto Rico. The average yield of tobacco per *cuerda*, in these two municipalities is 600 and 700 pounds respectively.† On the farms surveyed, the average yield of tobacco was 450 pounds per *cuerda*, which is much lower than the average for the regions where most of these farms were located.

The average yields obtained per *cuerda* of bananas, plantains, corn, beans, and "yautías" might be considered satisfactory for these farms, in view of the fact that these minor crops are generally grown on the poorer soils, or for some other purpose besides cash crops.

The yields of the crops included in table 5 were used as a basis in the calculation of the crop index for each farm.

TABLE 5. CROP YIELDS
224 COFFEE FARMS, PUERTO RICO, 1934

Crop	Number of cuerdas harvested	Average yield per cuerda
Coffee	11,577	92 pounds
Sugar cane	192	492 quintals*
Tobacco	302	4.5 quintals
Bananas	3,070	9.2 thousands
Plantains	125	6.5 thousands
Corn	345	6.0 quintals
Beans	246	2.8 quintals
Yautías	124	22.4 quintals

* One quintal is equivalent to 100 pounds.

† F. Joglar Rodríguez, Puerto Rico Agricultural Experiment Station, Extension Bulletin No. 4, "Cultivo del Tabaco", Appendix Table 1.

CROP SALES

The total receipts from the sale of crops in the 224 coffee farms amounted to $214,723, or an average of $1,460 per farm. Of this, 65.7 per cent was solely from coffee; 10.0 per cent from bananas; 5.7 per cent from sugar cane; 5.6 per cent from tobacco; 4.8 per cent from oranges; 2.7 per cent from plantains; and 5.5 per cent from the sale of other crops (table 6).

The average farm price obtained on these farms per quintal (100 pounds) of coffee in 1934 was $21.32. The 5-year average price per exported quintal, for the 1930–1934 fiscal years, was $25.20.†

The farm price of coffee in Puerto Rico since 1928 has tended to drop in spite of the small supply, due principally to the depression and to the fact that during this period there has been heavy smuggling of cheap foreign coffee into the Island. Sugar cane and tobacco prices have also dropped during this period.

Such crops as oranges, plantains, and bananas, which are usually delivered at the farm to be sold at the local town markets, had also very low prices during 1934.

TABLE 6. CROP SALES

224 COFFEE FARMS, PUERTO RICO, 1934

Crop	Quantity sold	Total sales	Average price per unit of sale	Sales per farm	Per cent of total
Coffee	10,072*	$214,723	$21.32	$959	65.7
Sugar cane	94,147*	18,743	0.20	84	5.7
Tobacco	1,209*	18,320	15.15	82	5.6
Oranges	6,794**	15,576	2.29	69	4.8
Plantains	677**	8,924	13.18	40	2.7
Bananas (all kinds)	20,684**	32,650	1.58	146	10.0
Other crops	.....	18,196	.....	80	5.5
Total	.....	$327,132	.....	$1,460	100.0

* Quintals. ** Thousands.

LIVESTOCK

There was a wide variety of livestock on these farms, although the average value of livestock per farm was only $286. Most farmers kept some dairy cattle and work animals besides their usual small poultry flock.

† Weighted average computed from figures in the 1934 Yearbook of Statistics of the Department of Agriculture and Commerce of Puerto Rico, based on reports of the United States Customs House.

DAIRY CATTLE

Dairy cows were commonly kept on these coffee farms, mainly for the milk, which was used for home consumption. In some cases a part of the milk was sold to neighboring farmers or retailed at a near-by town.

The "native" cow was the predominant breed, in spite of its low milk production. A few Holstein, Jersey, and Guernsey grades were found on some farms.

The value of all dairy cattle kept on these farms was $133 per farm, or nearly 50 per cent of the total value of all livestock (table 7).

WORK ANIMALS

Work animals on these farms included oxen, horses, mules, and donkeys. Oxen were most numerous on those farms which grew sugar cane in addition to coffee. They were used mostly for plowing the fields and hauling the cane during harvest time.

Horses, mules, and donkeys were mostly used as pack animals for the transportation of produce from the farm to the local town markets. This method of transportation was most common on those farms where transportation facilities were poor because of the absence of suitable roads. The average value of all work animals on those farms was $113.

POULTRY

A small poultry flock was found on each of the farms surveyed. This flock was kept mainly to supply the family needs for eggs and chickens. Practically all of the birds were of the game breed, with but few cases in which Rhode Island Reds, White Leghorns, or other improved poultry breeds were kept. The total value of the poultry flock was $19 per farm.

OTHER LIVESTOCK

Swine were kept on most farms. The average value was $7 per farm. On many of the farms surveyed, swine provided the farmer and his family with most of the year's supply of lard, pork, and a wide variety of sausages and other products.

Goats and sheep are uncommon on coffee farms. Most farmers object to them because of the large amount of damage they do to crops.

Bees were very common several years ago on coffee farms in Puerto Rico. Because of the low price of honey during the past few years, most farmers have discontinued keeping bees.

The average value per head of stock was an indication of the poor quality of livestock kept on these coffee farms, and, consequently, showed the need for improvement. The average production of milk per cow during 1934 was only 530 quarts, of which 19 per cent was sold, thus leaving 429 quarts of milk for home use during the year. This amount of milk was hardly sufficient to supplement the needs of the average family on a coffee farm. By increasing the number of Holstein, Jersey, and Guernsey grades and improving the feeding practice, improvement along this line could be readily obtained.

TABLE 7. LIVESTOCK
224 COFFEE FARMS, PUERTO RICO, 1934

Type	Average per farm		Value per head of stock
	Number	Value	
DAIRY CATTLE:			
Cows	3.5	$100	$29
Heifers—1 year old or over	1.3	16	12
Heifers—under 1 year old	0.5	3	6
Calves	1.1	6	5
Bulls	0.4	8	20
Total		$133	
WORK ANIMALS:			
Oxen	0.7	$24	$34
Horses	1.5	44	29
Mules	1.1	44	40
Donkeys	0.1	1	10
Total		$113	
POULTRY:			
Hens	21.3	$11	$0.52
Roosters	2.7	4	1.48
Pullets	13.9	4	0.29
Other fowl	0.1	*	
Total		$19	
OTHERS:			
Swine	1.1	$7	$6
Goats and sheep	0.3	1	3
Rabbits	0.4	*	
Bee hives	5.9	13	2
Total		$286	

* Less than $1.

MISCELLANEOUS RECEIPTS

In addition to the income from the sale of crops or livestock, most farms had some miscellaneous source of income. The total income from these miscellaneous sources amounted to $23,640 in 1934, or an average of $106 per farm (table 8). Of these $106 per farm, $55 were from the sale of charcoal, which was made from the wood obtained from the pruning and topping off of the permanent shade trees. This work was usually done on a share basis with one of the hired men.

Second in importance was the income from the benefit and rental payments received from the Agricultural Adjustment Administration on those farms which also grew tobacco. The average income from this source was $28 per farm. Income from the sale of wood, fence posts, or other sources made up the balance of the miscellaneous receipts per farm. Man labor off farm was an insignificant source of income on these farms.

On the basis of the number of farms reporting, income from the Agricultural Adjustment Administration payments averaged $347 per farm; from the sale of charcoal, $126; from wood, $97; from fence posts, $85; from man labor off farm, $30; and $142 from other sources.

TABLE 8. MISCELLANEOUS RECEIPTS
224 COFFEE FARMS, PUERTO RICO, 1934

	Total	Average per farm reporting	Average per farm (all farms)
Charcoal	$12,203	$126	$55
Man labor off farm	61	30	.....
Wood	2,530	97	11
Fence posts	597	85	3
A. A. A.*	6,254	347	28
Other income	1,995	142	9
Total	$23,640	.....	$106

* Benefit and rental payments on the 1934 tobacco crop.

MACHINERY AND EQUIPMENT

The average value of all machinery and equipment on the farms studied was $358 per farm (table 9).

Depulping machines were the most common type of machinery found on coffee farms. Many different types of depulping machines were found on these farms, ranging from the hand machine, the overshot wheel type, and animal-power types to the gasoline engine and electric types. The value of these depulping machines was $100 per farm or $110 per machine.

The hot-air coffee drier is an expensive modern type of machine, and was found on only twelve of the farms studied.

Ox-carts were used mostly for hauling the sugar cane, although motor trucks were also being used on those farms within easy access of satisfactory roads.

All of the cultivation of the coffee bushes was done by hand. The average value of hand-cultivating equipment was not so high as would have been expected, because the hired men furnished their own equipment in most cases.

Though very little plowing is done in the coffee fields, some plows are to be found, especially in those farms growing crops other than coffee.

The almost complete absence of tractors from coffee farms was indicated by the fact that only one tractor was found on the 224 coffee farms. This particular farm had a large acreage in tobacco.

TABLE 9. MACHINERY AND EQUIPMENT

224 COFFEE FARMS, PUERTO RICO, 1934

Type	Number	Value	
		Total	Per farm (all farms)
Depulping machines	204	$22,392	$100
Motors	115	10,967	49
Bombo (hot-air coffee drier)	12	28,120	126
Trucks	11	5,515	25
Ox-carts	48	2,341	10
Horse-carts	2	34	...
Hand cultivating equipment	...	3,803	17
Plows	51	689	3
Harrows	7	106	...
Tractor	1	206	1
Trapiche*	1	77	...
Other	...	5,953	27
Total	...	$80,203	$358

* Small mill for grinding sugar cane at the farm.

FARM PRIVILEGES

Farm privileges include what the farmer got from his farm for his year's work besides his labor income. The yearly rental value of the farm house, plus all the farm and livestock products obtained during the year constituted the farm privileges. The value of the farm privileges for all farms studied averaged $451 during the year 1934 (table 10).

Minor produce, which included coffee, bananas, and minor crops from the farm used in the farmer's home, accounted for the major part of the privileges ($150). Next in importance was the yearly rental value of the farm house, which averaged $125. Milk was third in importance as a farm privilege, averaging $119 per farm. Other products, such as charcoal, eggs, livestock, wood, fruits, honey, lard, and sausages also constituted some of the farm privileges which these coffee farmers in Puerto Rico received.

The farm privileges, when added to the labor income, represented the labor earnings of the farmer. The average labor earnings for all of the farms studied was $669 per farm (table 11).

TABLE 10. FARM PRIVILEGES
224 COFFEE FARMS, PUERTO RICO, 1934

	Average per farm	
	Amount	Value
Milk (quarts)	1,484	$119
Eggs (dozens)	86	16
Livestock		11
Minor produce		150
Rent value of dwelling		125
Charcoal		19
Wood		7
Fruits		2
Honey, lard, and sausages		2
Total		$451

CASH FARM EXPENSES

The average cash farm expenses for all farms was $1,336 (table 11). Of this amount, 77.2 per cent was spent for labor; 8.5 per cent for taxes; 4.6 per cent for new buildings and repairs; 3.5 per cent for fertilizer; 2.3 per cent for livestock feed; and 3.9 per cent for other cash expenses.

LABOR

Labor was the most important item of expense on these farms, most of it being for hired day labor, which averaged $870 per farm, and $890 per farm reporting. Only 5 farms out of the 224 did not hire day labor in 1934. There were three farms operated by managers. The expense for manager's salary represented 1.1 per cent of the cash farm expenses, and amounted to $1,100 per year on those farms reporting. A "mayordomo", or foreman, was employed on 88 of the coffee farms. The expense for his salary was 8.0 per cent of the cash expenses per farm, and amounted to $272 per farm reporting. Labor compensation insurance averaged $40 per farm, and $59 per farm reporting.

TAXES

Taxes were the second most important group of cash farm expenses, averaging $113 per farm. The expense for taxes represented 8.5 per cent of the cash farm expenses, and 0.73 per cent of the average farm capital per farm.

LIVESTOCK FEED

Livestock feed averaged $31 per farm, of which $22 was for poultry feed. The expense for cattle feed averaged only $6 per farm. Since there were only 19 farms reporting cattle feed expense, the average per farm reporting was $72.

MISCELLANEOUS EXPENSES

Cash expenses for fertilizer averaged $45 per farm, and $179 per farm reporting. Fertilizer was purchased on 56 of the farms surveyed, but on only 17 of these farms it was applied to the coffee bushes. On the other farms it was applied either to sugar cane or to tobacco.

TABLE 11. CASH FARM EXPENSES
224 COFFEE FARMS, PUERTO RICO, 1934

	Total expense	Average per farm reporting	Average per farm (all farms)	Per cent of total
	Dollars	Dollars	Dollars	
LABOR:				
Manager's salary	3,300	1,100	15	1.1
Mayordomo's salary	23,973	272	107	8.0
Hired day labor	194,844	890	870	65.1
Labor compensation insurance	8,948	59	40	3.0
Total	231,065	.....	1,032	77.2
TAXES:				
Property tax	23,607	105	105	7.9
Coffee insurance tax	1,536	24	7	0.5
Tobacco protection tax	287	16	1	0.1
Total	25,430	.....	113	8.5
LIVESTOCK FEED:				
Cattle	1,377	72	6	0.4
Poultry	4,848	36	22	1.7
Other animal feed	719	90	3	0.2
Total	6,944	.....	31	2.3
Fertilizer	10,035	179	45	3.5
Insecticides	328	25	2	0.1
BUILDINGS:				
New	5,909	311	26	1.9
Repairs	7,798	134	35	2.7
Total	13,707	.....	61	4.6
Equipment:				
Purchased	531	59	2	0.1
Repairs	309	26	1	0.1
Total	840	.....	3	0.2
Transportation of produce	3,774	22	17	1.4
Hired animals	124	31	1	0.1
Shoeing horses	612	6	3	0.2
Seed purchased	1,529	27	7	0.5
Fences	1,824	27	8	0.6
Farm share auto	556	111	2	0.1
Truck	885	177	4	0.3
Bags	760	7	3	0.2
Toldas*	465	9	2	0.1
Gas and oil for depulping machine	481	5	2	0.1
Total	299,359	.....	1,336	100.0

* Burlap for drying coffee.

The expense for construction and repair of buildings averaged $61 per farm. New buildings were constructed on 19 farms at an average cost of $311.

Equipment costs were relatively insignificant on the 224 coffee farms. Of the other cash farm expenses, the most important was

that for the transportation of produce, which averaged $17 per farm, or 1.4 per cent of the cash farm expenses. Because of the fact that many farms lacked suitable roads, the transportation of the farm produce to the local market was slow and expensive. Such expenses as purchase of seed, bags, "toldas", and gas and oil for the depulping machine, although common, were of minor importance.

LABOR INCOME

Labor income is one of the most generally accepted measures of the business success of a farm. It represents what the farmer received for his year's work and management, in addition to having a house to live in and products furnished by the farm, after allowing a reasonable amount of interests on his capital invested in the farm business. It is comparable to the cash wages of a married hired man on a farm, who also receives the use of a house and farm products.

The average total receipts per farm was $1,633, most of which was derived from the sale of crops, especially coffee (table 11). The average total expenses per farm was $1,506. The value of the unpaid family labor as estimated by the farmer was included as an expense, since that would have been the approximate cost of hiring the work done. The increase in farm capital during the year was not enough to balance the decrease, resulting in a net decrease in farm capital, which was also charged as an expense.

The average total receipts exceeded the average total expenses on these farms by $127. This was the farm income, or the amount which the operator received for his year's work and for the use of the capital invested. In order to put all farms on a comparable basis, regardless of mortgage indebtedness, 8 per cent interest on the average capital invested was deducted from the farm income to obtain the labor income.

The average labor income on these 224 farms was $–1,120 per farm. This means that, on the average, these farmers failed by $1,120 to meet their total farm expenses and interest on investment, and received nothing for their year's work.

A farmer's labor income might be nothing, or even less than nothing, as in this case, and yet he might be making a living. If the farm income were $500 and the capital invested were $10,000, the labor income would be $500 less 8 per cent on the $10,000 capital ($800), or minus $300. However, if he had no mortgage nor any other debt, the farmer would have $500 to live on. If he had had a son working at the farm who was not paid wages, but whose time

was included in the expenses as $200, the family would then have had $700 to live on. The farmer might thus be living well, in spite of having a negative labor income.

Labor earnings is the labor income plus the value of the farm privileges. The average value of farm privileges per farm (table 10) was $451, which, when added to the labor income, resulted in an average labor earnings of $–669 per farm.

The return on capital is calculated by subtracting the value of the operator's time, as estimated by the farmer, from the farm income. The farm income, as already stated, represents the amount the operator received for his year's work and the use of his farm capital. By subtracting the estimated value of the operator's time from the farm income, the return on his capital invested is obtained. The average return on capital for these farms was $–377.

TABLE 12. LABOR INCOME SUMMARY
224 COFFEE FARMS, PUERTO RICO, 1934

	Total	Average per farm
RECEIPTS:		
Crops sold	$327,132	$1,460
Livestock sold	3,973	18
Livestock products sold	10,891	49
Miscellaneous	23,640	106
Total	$365,636	$1,633
EXPENSES:		
Cash farm expense	$299,359	$1,336
Livestock purchased	2,026	9
Unpaid labor	20,659	92
Net decrease in farm capital	15,296	69
Total	$337,340	$1,506
Farm income	28,296	127
Less: 8 per cent interest on average farm capital	279,207	1,247
Labor income:	**$-250,911**	**$-1,120**
Labor earnings	-149,904	-669
Return on capital	-84,528	-377
Per cent return on capital	-2.42	-2.42
Value of operator's time	112,824	504
Capital turnover		9.54

The per cent return on capital is the return on capital expressed as a percentage of the average farm capital. These farmers had an average of $15,580 invested in their farm businesses. The return on this capital averaged minus $377, or minus 2.42 per cent of the capital.

Capital turnover is the number of years required for receipts to equal capital. An average of 9.54 years, as obtained for these coffee farms, indicates a very slow capital turnover during 1934.

TOTAL CUERDAS IN COFFEE AND LABOR INCOME

Total *cuerdas* in bearing and non-bearing coffee was a satisfactory measure of size of business in the farms studied. The farms were divided into five different groups, according to total *cuerdas* in coffee per farm. In each of these groups the average labor income obtained was a negative figure, indicating a loss (table 13).

The group containing the smallest farms has 16 *cuerdas* in coffee, and made a labor income of $–344. The second group, with 49 *cuerdas* in coffee, made a labor income of $–663. In the third group there were 96 *cuerdas* in coffee, and the labor income was $–1,264. The fourth group had 149 *cuerdas* in coffee and averaged $–1,656 labor income. The group with the largest farms had 274 *cuerdas* in coffee, and made a labor income of $–3,180. The relation between total *cuerdas* in coffee and labor income indicated that the greater the number of *cuerdas* in coffee, the larger was the loss.

Size of business may have a direct or an indirect relationship to labor income, depending on whether the crop year was good or poor. There were many conditions that made 1934 a poor crop year for coffee farmers in Puerto Rico: low yields of coffee were obtained; a large percentage of the coffee bushes was not yet bearing; and prices for coffee had also dropped. Under such conditions the larger farms would be expected to lose more money than the smaller farms.

Other measures of size of business, such as total *cuerdas* per farm, capital invested, and gross receipts, had the same relation to labor income as did total *cuerdas* in coffee. The larger the size of the farm business, as measured by each of these other factors, the greater the loss, as indicated by the labor incomes. Mortgage debts per farm, both Federal Land Bank and Hurricane Relief Commission mortgages, increased together with size of farm.

Yield and crop index did not show the same relationship to labor income with increasing acreage in coffee as did the measures of size of business. There was a curvilinear relationship, indicating that high yields could be obtained on small farms as well as on large farms.

As the total *cuerdas* in coffee increased the per cent income from coffee also increased, indicating that the larger farms had less diversification and were thus more dependent on sales of coffee for their income.

TABLE 13. RELATION OF TOTAL CUERDAS IN COFFEE TO LABOR INCOME AND OTHER FACTORS

224 COFFEE FARMS, PUERTO RICO, 1934

	Total cuerdas in coffee					Average for all farms
	Less than 30	30-79	80-129	130-179	180 or more	
Number of farms	63	71	36	23	31	224
Cuerdas in coffee:						
Bearing	10	31	51	93	154	52
Non-bearing	6	18	45	56	120	37
Total	16	49	96	149	274	89
Labor income	$-344	$-363	$-1,264	$-1,656	$-3,180	$-1,120
Farm income	$52	$78	$-143	$364	$526	$127
SIZE FACTORS:						
Size of farm (cuerdas)	59	114	203	309	489	186
Total cuerdas in crops	27	72	124	196	333	117
Net cuerdas in crops	20	55	101	157	290	96
Capital invested	$4,945	$9,265	$14,008	$25,250	$46,320	$15,580
Gross receipts	$545	$1,037	$1,439	$2,915	$4,764	$1,633
Receipts from coffee sales	$185	$516	$750	$1,767	$3,218	$963
Federal Land Bank mortgage	$1,675	$2,542	$3,639	$7,630	$9,468	$3,955
Hurricane Relief Commission mortgage	$944	$2,190	$3,861	$6,022	$8,855	$3,424
Man equivalent	3.0	4.8	8.0	12.2	19.4	7.5
EFFICIENCY FACTORS:						
Yield of coffee per cuerda (pounds)	112	96	84	97	107	92
Crop index	120	98	94	105	110	103
Gross returns per cuerda	$12	$10	$8	$10	$10	$10
Cuerdas in crops per man equivalent	7.5	13.2	15.2	15.5	17.5	12.7
Coffee sales per man equivalent	$62	$108	$94	$145	$166	$76
Per cent income from coffee	50	56	59	65	74	58

TOTAL CUERDAS PER FARM AND LABOR INCOME

There were 42 farms of less than 50 *cuerdas* in size. The average labor income for this group of farms was $–230. These farms had 15 *cuerdas* in coffee, and their average farm capital was $3,069 (table 14).

The second group consisted of 82 farms, averaging 90 *cuerdas* per farm, and with a labor income of $–718. This group had 48 *cuerdas* in coffee and $8,552 in capital.

In the last group are included 31 farms whose size was 350 *cuerdas* or more. The average size of farm in this group was 547 *cuerdas*, and their labor income $–2,868. They had 245 *cuerdas* in coffee and a capital of $43,805.

The relation existing between total *cuerdas* per farm and labor income indicated that as the size of farm increased the acreage in coffee, capital invested, and *cuerdas* in crops per man equivalent also increased, but the labor income decreased. This relation points again to the fact that, during 1934, the larger farms lost more money than did the smaller farms.

TABLE 14. RELATION OF SIZE OF FARM TO LABOR INCOME AND OTHER FACTORS

224 COFFEE FARMS, PUERTO RICO, 1934

Siz of farm (cuerdas)		Number of farms	Total cuerdas in coffee	Capital invested	Cuerdas in crops per man equivalent	Labor income
Range	Average					
Less than 50	27	42	15	$3,069	7.4	$-230
50–149	90	82	48	8,532	13.1	-718
150–249	199	47	95	16,224	13.9	-1,184
250–349	291	22	146	24,532	14.7	-1,718
350 or more	547	31	245	43,805	16.0	-2,868

CUERDAS IN BEARING COFFEE AND LABOR INCOME

The number of *cuerdas* in bearing coffee was a good measure of size of business. On these 224 coffee farms it showed the same relationship to labor income as did the other measures of size (table 15).

The first group consisted of 106 farms averaging 14 *cuerdas* of bearing coffee per farm, and a man equivalent of 4.1. Fifty per cent of their total income was from the sale of coffee. The average farm income for this group of farms was $–21, and the labor income $–556.

In contrast with these small farms the 20 largest farms had an average of 194 *cuerdas* in bearing coffee and a man equivalent of 18.6. About three-fourths of the receipts on these farms were from the sale of coffee. These farmers made $793, besides paying all their farm expenses. Their labor incomes, however, were much lower than those for the first group of farms. They averaged $–3,181. This was due to the fact that the large farms had a much greater investment in capital. The farm income on these farms was not large enough to allow for the 8 per cent interest deduction, and, consequently, a large negative labor income resulted. If all the farms had been completely out of debt, the larger farms would have been much better off than the smaller farms, since they made approximately $800 above expenses.

TABLE 15. RELATION OF CUERDAS IN BEARING COFFEE TO LABOR INCOME AND OTHER FACTORS

224 COFFEE FARMS, PUERTO RICO, 1934

Cuerdas in bearing coffee		Number of farms	Man equivalent	Per cent income from coffee	Farm income	Labor income
Range	Average					
Less than 30	14	106	4.1	50	$-21	$-556
30–79	51	74	7.1	62	100	-1,061
80–129	103	24	15.5	71	303	-2,078
130 or more	194	20	18.6	73	793	-3,181

NET CUERDAS IN CROPS AND LABOR INCOME

An indirect relationship was observed between net *cuerdas* in crops and labor income. Labor income decreased as the average number of net *cuerdas* in crops in each group of farms increased (table 16).

The smaller farms with 27 net *cuerdas* in crops, including 24 in coffee, had an average capital of $5,773. The yield obtained was 108 pounds of coffee per *cuerda,* and the labor income $–424. Fifty-four per cent of the gross income on these farms was from the sale of coffee. Labor costs averaged $11 per *cuerda* in crops, and there were 9.1 *cuerdas* in crops per man equivalent.

The large farms averaged 294 net *cuerdas* in crops, 274 *cuerdas* in coffee, and had a capital of $47,017. The yield of coffee was 106 pounds per *cuerda,* and the labor income $–3,119. Seventy-one per cent of the income was from coffee sales. Labor costs averaged $10, and there were 17.1 *cuerdas* in crops per man equivalent.

Yield of coffee per *cuerda* was low for each group of farms in general. There was no relation between net *cuerdas* in crops and yield of coffee per *cuerda.*

As the net *cuerdas* in crops increased, the per cent income from coffee also increased, indicating that the larger farms were more dependent on coffee for their income. Labor costs per *cuerda* in crops tended to remain fairly constant as the size of farm business increased.

TABLE 16. RELATION OF NET CUERDAS IN CROPS TO LABOR INCOME AND OTHER FACTORS

224 COFFEE FARMS, PUERTO RICO, 1934

Net cuerdas in crops		Number of farms	Total cuerdas in coffee	Capital invested	Yield of coffee per cuerda (*Pounds*)	Per cent income from coffee	Cuerdas in crops per man equivalent	Labor costs per cuerda in crops	Labor income
Range	Average								
Less than 50	27	96	24	$5,773	108	54	9.1	$11	$–424
50-99	73	55	67	11,608	86	56	15.0	10	–920
100-149	118	25	111	17,686	99	59	15.0	12	–1,382
150-199	167	18	158	24,728	105	68	15.3	11	–1,750
200 or more	294	30	274	47,017	106	71	17.1	10	–3,119

CAPITAL INVESTED AND LABOR INCOME

There was a marked relationship between the amount of capital invested and the labor income on the farms studied. The larger the capital invested, the greater the loss (table 17).

The first group of farms, with an average capital of $2,959, had a total area of 40 *cuerdas*, 20 of which were in coffee. The gross receipts for this first group of farms averaged $373, of which $161 was from the sale of coffee. This group of farms had an average labor income of $–267.

The last group of farms had an average capital of $44,224 and 447 *cuerdas* per farm, with 237 *cuerdas* in coffee. Gross receipts amounted to $4,569 per farm, including $2,955 from the sale of coffee. This group had an average labor income of $–2,894.

Considering the facts that coffee yields in 1934 were unusually low and that most of the farmers actually lost money in their businesses, it was reasonable to expect that the larger the amount of capital invested in the farm business, the greater would be the loss.

The amounts of Federal Land Bank mortgages, as well as those of the Hurricane Relief Commission increased, together with capital invested. However, when the mortgage indebtedness from these two sources was expressed as a percentage of the farm capital, the larger farms had 40 per cent, while the smaller farms had approximately 60 per cent. The average mortgage debt held by these two agencies on the 224 coffee farms was 47 per cent of the farm capital.

TABLE 17. RELATION OF CAPITAL INVESTED TO LABOR INCOME AND OTHER FACTORS

224 COFFEE FARMS, PUERTO RICO, 1934

Capital invested (dollars)		Number of farms	Size of farm (*cuerdas*)	Total cuerdas in coffee	Gross receipts	Coffee sales	Federal Land Bank mortgages	Hurricane Relief Commission mortgages	Labor income
Range	Average								
Less than 5,000	$2,959	55	40	20	$373	$161	$1,082	$700	$–267
5,000— 9,999	7,450	57	110	46	964	443	2,237	1,974	–575
10,000—14,999	12,047	36	169	76	1,193	744	3,389	2,805	–978
15,000—24,999	19,912	37	251	111	2,107	1,069	5,635	5,851	–1,496
25,000 or more	44,424	39	447	237	4,569	2,955	9,449	7,651	–2,894
Average (all farms)	15,580	224	186	89	1,633	963	3,955	3,424	–1,120

GROSS RECEIPTS AND LABOR INCOME

The relation between gross receipts and labor income was also indirect. There were 61 farms with gross receipts of less than $500, averaging $258 per farm (table 18). These farms had 30 *cuerdas* in coffee, and a crop index of 91. They were short by $176 in meeting their total farm expenses, and their average labor income was $–596.

Gross receipts of $2,000 or more were obtained in 49 farms. The average was $4,779 per farm. This group of farms had 193 *cuerdas* in coffee and a crop index of 139. After paying all the farm expenses, these farmers made $1,033; but even then their labor income was $–1,849. If these farms had had no mortgage indebtedness, the farmers would have had an income of $1,033 to live on, and, consequently, would have been much better off than those farmers in the first group of farms.

Total *cuerdas* in coffee and crop index were closely associated with gross receipts. Both varied directly with gross receipts, and were causal factors in determining the amount of gross receipts per farm.

TABLE 18. RELATION OF GROSS RECEIPTS TO LABOR INCOME AND OTHER FACTORS

224 COFFEE FARMS, PUERTO RICO, 1934

Gross receipts (dollars)		Number of farms	Total cuerdas in coffee	Crop index	Yield of coffee per cuerda (*Pounds*)	Coffee sales	Animal units	Farm income	Labor income
Range	Average								
Less than 500	258	61	30	91	74	163	3.0	$–175	$–596
500-999	713	52	51	96	90	371	5.1	–192	–830
1,000-1,499	1,233	42	87	103	105	630	8.7	–91	–1,180
1,500-1,999	1,701	20	112	105	103	1,005	10.9	–121	–1,563
2,000 or more	4,779	49	193	139	137	2,803	21.2	–1,033	–1,849

MAN EQUIVALENT AND LABOR INCOME

The relation between man equivalent and labor income was the same as that for other measures of size of business already discussed. The larger the man equivalent in any group of farms, the smaller the labor income (table 19).

Fifty of the farms studied had less than 3.0 man per farm. The average labor income on these farms was $–281. There were 54 *cuerdas* per farm, 22 of which were in coffee. Crop index averaged 101; *cuerdas* in crops per man equivalent, 11.9; labor costs per *cuerda* in crops, $7; and coffee sales per man equivalent, $84.

In contrast with this group of small farms, the 40 largest farms had an average of 20.0 man, and a labor income of $–2,714. These farms had 10 times as many *cuerdas* in coffee as the small farms; the crop index was only about 20 per cent higher; *cuerdas* in crops per man equivalent were practically the same; and labor costs per *cuerda* in crops doubled. Labor costs per *cuerda* in crops showed a direct relationship to man equivalent. However, this increased cost of labor did not produce an increased efficiency in the use of labor,

since there was no relation between crop index or *cuerdas* in crops per man equivalent and number of men per farm.

Coffee sales per man equivalent increased steadily from $84 in the small farms to $149 in the large farms. This direct relationship was partly due to the fact that the larger farms were more dependent on coffee for their income.

TABLE 19. RELATION OF MAN EQUIVALENT TO LABOR INCOME AND OTHER FACTORS

224 COFFEE FARMS, PUERTO RICO, 1934

Man Equivalent		Number of farms	Size of farm (*Cuerdas*)	Total cuerdas in coffee	Crop index	Cuerdas in crops per man equivalent	Labor costs per cuerda in crops	Coffee sales per man equivalent	Labor income
Range	Average								
Less than 3.0	2.1	50	54	22	101	11.9	$7	$84	$–281
3.0–5.9	4.4	84	112	49	105	12.3	11	104	–697
6.0–8.9	7.4	29	203	99	95	14.7	11	107	–1,328
9.0–11.9	10.2	21	256	134	105	14.5	12	124	–1,487
12.0 or more	20.0	40	447	225	122	12.4	14	149	–2,714

GROSS RETURNS PER CUERDA AND LABOR INCOME

The relation between gross returns per *cuerda* and labor income showed that, in general, the larger the gross returns per *cuerda*, the smaller the losses. This relation was true particularly on those farms with gross returns of more than $5 per *cuerda* (table 20).

Of the 224 coffee farms, 58 had a gross return per *cuerda* of less than $5. They made a farm income of $–816 and a labor income of $–1,269. This group of farms had an average of 74 *cuerdas* in coffee, a crop index of 70, and 14.2 *cuerdas* in crops per man equivalent.

The second group consisted of 82 farms, with an average of $7 gross returns per *cuerda*, a farm income of $–125, and a labor income of $–1,455. The labor income for this group of farms decreased in spite of the higher gross returns per *cuerda*, crop index, acreage in coffee, and farm income obtained; thus indicating that these farms were over-capitalized.

The group of farms with the largest gross returns per *cuerda* averaged $29. The farm income was $1,085, and the labor income was $–109. The crop index for this group was 2.3 times as large as that of the first group. These farms had 8.3 *cuerdas* in crops per man equivalent.

This table showed that gross returns per *cuerda* were directly associated with crop index and farm income; indirectly associated with *cuerdas* in crops per man equivalent and labor income; and had no definite relationship to total *cuerdas* in coffee.

TABLE 20. RELATION OF GROSS RETURNS PER CUERDA TO LABOR INCOME AND OTHER FACTORS

224 COFFEE FARMS, PUERTO RICO, 1934

Gross returns per cuerda (Dollars)		Number of farms	Crop index	Total cuerdas in coffee	Cuerdas in crops per man equivalent	Farm income	Labor income
Range	Average						
Less than 5...	3	58	70	74	14.2	$-316	$-1,269
5-9.....	7	82	97	103	14.1	-125	-1,455
10-14.....	11	39	126	97	11.9	415	-1,019
15-19.....	17	19	132	86	10.3	656	-811
20 or more....	29	26	164	63	8.3	1,085	-109

CROP INDEX AND LABOR INCOME

Crop index was directly associated with labor income. As the average crop index in each of the five groups of farms increased from 40 to 254, the average labor income also increased from $-1,486 to $-113 (table 21). In other words, the group of farms having an average crop index of 40 lost approximately 13 times as much money as the group of farms with an average crop index of 254.

Cuerdas in bearing coffee had no direct relationship to crop index. The relation appeared to be curvilinear, showing that the first group of farms which had the largest number of *cuerdas* in bearing coffee had the lowest crop index; while the last group of farms, with practically the same acreage in bearing coffee, had the highest crop index.

Man equivalent increased together with crop index, while *cuerdas* in crops per man equivalent decreased. This indicated that, as crop index increased, more labor was required to harvest a *cuerda* of coffee. Consequently, a man could not be able to harvest as many *cuerdas* of coffee as when the crop index was low.

Yield of coffee per *cuerda* also increased together with the crop index. Since the crop index itself was heavily weighted by the yield of coffee, their magnitudes were in all cases very similar.

Gross returns per *cuerda* increased from $7 in the first group to $24 in the last group of farms. Labor costs per *cuerda* in crops increased from $8 to $16 in the first and last group respectively. Coffee sales per man equivalent averaged $64 in the first group of

farms, and increased to $273 in the last group. The farm income had also a direct relationship to crop index, increasing from $–40 to $1,759.

In general, a higher crop index implied the employment of more men and increased labor costs per *cuerda* in crops. The increasing yields and the more intensive cultivation involved reduced the number of *cuerdas* in crops per man equivalent, but increased the gross returns per *cuerda* and the coffee sales per man equivalent, thus offsetting the higher labor costs. This resulted in an increase in the farm income and labor income.

The statement that crop yields, especially of coffee, were low during 1934 is again supplemented by the fact that even those farms with a crop index 2.54 times the average crop index for all farms were not able to make a positive labor income.

TABLE 21. RELATION OF CROP INDEX TO LABOR INCOME AND OTHER FACTORS

224 COFFEE FARMS, PUERTO RICO, 1934

Crop index		Number of farms	Cuerdas in bearing coffee	Man equivalent	Cuerdas in crops per man equivalent	Yield of coffee per cuerda (*pounds*)	Gross returns per cuerda	Labor costs per cuerda in crops	Coffee sales per man equivalent	Farm income	Labor income
Range	Average										
Less than 50	40	40	60	5.9	16.8	39	$7	$8	$64	$-401	$-1,486
50—99	76	86	58	7.1	15.6	66	8	10	110	-84	-1,242
100—149	124	50	39	8.3	10.5	120	11	12	109	308	-1,024
150—199	169	33	40	8.3	10.9	173	11	13	158	291	-964
200 or more	254	15	59	11.0	9.0	236	21	16	273	1,759	-113

YIELD OF COFFEE PER CUERDA AND LABOR INCOME

There was a direct relationship between yield of coffee per *cuerda* and labor income, especially on those farms with yields of more than 50 pounds of coffee per *cuerda* (table 22).

The yield of coffee per *cuerda*, on most of the farms studied, was considerably lower than what is generally considered a satisfactory yield of coffee in Puerto Rico. Fifty-eight farms had yields of less than 50 pounds of coffee per *cuerda*, averaging 32 pounds. On these farms the farm income was $–194, and the labor income $–1,180. These farms averaged 144 *cuerdas* in size, 55 of which were in bearing coffee. The crop index was 58, gros returns per *cuerda* $6, and coffee sales per man equivalent $62.

The second group included 76 farms with an average yield of 69 pounds per *cuerda*. On this group, the farm income increased to

$–79, but the labor income decreased, instead of increasing, to $–1,385. This decrease in the labor income, in spite of the increase in yield, *cuerdas* in bearing coffee, crop index, gross returns per *cuerda,* coffee sales per man equivalent and farm income, was due to the fact that the average capital invested on these farms was too large compared to that of the preceding group. The increase in farm income was not enough to cover the interest charge on this large capital, and, consequently, the labor income decreased.

There were 24 farms with an average yield of 255 pounds of coffee per *cuerda,* which represented 2.8 times the average yield for all farms. These farms made a farm income of $886, but were not able to make a positive labor income. The fact that the yield of coffee per *cuerda* in the farms studied was very low during 1934 was thus observed again.

Size of farm business, measured either by total *cuerdas* in farm, *cuerdas* in bearing coffee, or capital invested, did not show any relation to yield of coffee per *cuerda.*

TABLE 22. RELATION OF YIELD OF COFFEE PER CUERDA TO LABOR INCOME AND OTHER FACTORS

224 COFFEE FARMS, PUERTO RICO, 1934

Yield of coffee per cuerda (pounds)		Number of farms	Size of farm *cuerdas*	Cuerdas in bearing coffee	Capital invested	Crop index	Gross returns per cuerda	Coffee sales per man equivalent	Farm income	Labor income
Range	Average									
Less than 50	32	58	144	55	$12,322	58	$6	$62	$–194	$–1,180
50—99	69	76	197	61	16,321	82	9	108	–79	–1,385
100—149	123	42	199	38	16,195	126	10	117	148	–1,148
150–199	168	24	245	54	20,108	162	12	179	760	–846
200 or more	255	24	153	34	15,520	206	20	240	886	–356

LABOR COSTS PER CUERDA IN CROPS AND LABOR INCOME

On 27 of the farms studied, the labor costs were less than $5 per *cuerda* in crops; there were 30 *cuerdas* in coffee; and the labor income was $–615 (table 23).

Sixty-one farms had labor costs of $10 to $14 per *cuerda* in crops; 103 *cuerdas* in coffee; and made a labor income of $–1,456. On 20 farms, with average labor costs of $26 per *cuerda* in crops and 42 *cuerdas* in coffee, the labor income was $–1,066. This showed that labor costs per *cuerda* in crops had a curvilinear relationship to total *cuerdas* in coffee and to labor income.

Crop index and gross returns per *cuerda* were much higher for the last two groups of farms than for the first three. These two factors caused the curvilinear relationship stated above.

Cuerdas in crops per man equivalent had an indirect relation to labor costs per *cuerda* in crops. This indicated that with higher labor costs, the coffee farms were more intensively cultivated.

TABLE 23. RELATION OF LABOR COSTS PER CUERDA IN CROPS TO LABOR INCOME AND OTHER FACTORS

224 COFFEE FARMS, PUERTO RICO, 1934

Labor costs per cuerda in crops (dollars)		Number of farms	Total cuerdas in coffee	Crop index	Yield of coffee per cuerda (pounds)	Cuerdas in crops per man equivalent	Gross returns per cuerda	Coffee sales per man equivalent	Labor income
Range	Average								
Less than 5	3	27	30	63	52	18.2	$5	$81	$-615
5-9	7	88	98	102	93	15.7	10	148	-1,024
10-14	12	61	103	104	103	10.8	8	108	-1,456
15-19	17	28	98	145	141	8.0	14	165	-1,216
20 or more	26	20	42	133	134	5.1	18	78	-1,066

PER CENT INCOME FROM COFFEE AND LABOR INCOME

The relation between per cent income from coffee and labor income showed that, in general, the larger the per cent income from coffee, the smaller the labor income (table 24). This relation was constant throughout the table, except in the last group of farms. The labor income on this last group increased instead of decreasing, as compared to that of the preceding group.

The last group of farms consisted of 41 farms, with an average of 95 per cent of their income being from coffee. The increase in labor income was due to a much larger crop index, yield of coffee, and coffee sales per man equivalent, over the preceding group of farms. Gross returns per *cuerda* and *cuerdas* in coffee were also somewhat larger. The farm income, which had been decreasing, also showed a decided increase in this last group.

TABLE 24. RELATION OF PER CENT INCOME FROM COFFEE TO LABOR INCOME AND OTHER FACTORS

224 COFFEE FARMS, PUERTO RICO, 1934

Per cent income from coffee		Number of farms	Total cuerdas in coffee	Crop index	Yield of coffee per cuerda (pounds)	Gross returns per cuerda	Coffee sales per man equivalent	Farm income	Labor income
Range	Average								
Less than 30	15	44	52	104	82	$13	$44	$378	$-570
30-59	46	63	82	103	96	11	119	279	-946
60-89	75	73	104	93	94	8	127	-218	-1,575
90 or more	95	41	119	135	138	10	210	240	-1,180

USE OF FERTILIZER ON COFFEE AND LABOR INCOME

Only 17 of the 224 farms studied applied any kind of commercial fertilizer to the coffee bushes (table 25). This limited number of farms using fertilizer was too small to attempt any grouping based on quantity of fertilizer applied per *cuerda*.

Those farms using some fertilizer on coffee made an average labor income of $–796, which was $351 higher than that for the farms using no fertilizer. The farm income increased $446; yield of coffee per *cuerda* was 21 per cent higher; and the crop index showed a 28 per cent increase. Gross returns per *cuerda* were 70 per cent higher, in spite of the larger size of the farms in this group.

The increases noted above are not to be attributed solely to the application of fertilizer, since the number of farms reporting such applications was very small, and the cost of such fertilizer averaged only approximately $3 per *cuerda*. There were other factors also responsible for these increases. About one-third of the farms using fertilizer on coffee had other important cash crops, such as sugar cane, tobacco, or plantains, on which fertilizer was also used.

TABLE 25. RELATION OF USE OF FERTILIZER ON COFFEE TO LABOR INCOME AND OTHER FACTORS

224 COFFEE FARMS, PUERTO RICO, 1934

Factor	Farms using no fertilizer on coffee	Farms using some fertilizer on coffee
Number of farms	207	17
Labor income	$–1,147	$–796
Farm income	$92	$538
Yield of coffee per cuerda (pounds)	99	120
Crop index	104	133
Gross returns per cuerda	$13	$17
Size of farm (cuerdas)	180	235

RELATION OF SIZE OF FARM AND TYPE OF MANAGEMENT TO LABOR INCOME

The majority of the farms included in this study were operated by the owners themselves. However, when, for some reason or other, the owner was not able to live on his farm, or when the farm business was too big for him to attend alone, he usually hired a "mayordomo", or foreman. A *mayordomo* is a skilled laborer who has had experience in coffee farming and who is given a house to live in and farm privileges besides his regular wage. Usually he is well acquainted with the farm, and is in a position to run the farm business successfully. Some of these *mayordomos* had actually been owners of coffee farms themselves. Only three of the farms studied were operated by managers (table 26).

For the purpose of this analysis, the farms were divided into two groups: those of less than 200 *cuerdas* and those of 200 or more *cuerdas* in size. In each of these groups the farms operated by the owners made higher labor incomes than those operated either by the owner and a *mayordomo* or by a manager.

The average labor income on the smaller farms was $–445, when operated by the owner, and $–1,058, when operated by owner and *mayordomo*. The owner-*mayordomo* operated farms had twice as many *cuerdas* in coffee and nearly twice as much capital invested, but the crop index and gross returns per *cuerda* were lower than those on the owner-operated farms.

The large farms operated by the owners made a labor income of $–1,760. Those operated by the owner and a *mayordomo* made $–2,211, while the farms operated by managers made a labor income of $–3,825. Crop index, yield, and gross returns per *cuerda* were highest on this last group of farms, but yet they had the largest loss. This was due mostly to the large capital investment and increased cost of labor.

When the farms were operated by the owners they were able to make $85 above expenses on the small farms and $259 on the large farms. In both cases the labor income was a negative figure, the larger farms losing about 4 times as much money as the small farms.

Small farms operated by the owner and a *mayordomo* lacked $167 to meet expenses, and made a labor income of $–1,058. In contrast, the large farms operated by the owner and a *mayordomo* made $376 above expenses; but their labor income was $–2,211.

None of the small farms was operated by a manager. The three large farms under this type of management had a farm income of $–181 and a labor income of $–3,825.

TABLE 26. RELATION OF SIZE OF FARMS UNDER DIFFERENT TYPES OF MANAGEMENT TO LABOR INCOME AND OTHER FACTORS

224 COFFEE FARMS, PUERTO RICO, 1934

Size of farm (cuerdas)	Average size of farm (cuerdas)	Number of farms	Total cuerdas in coffee	Gross returns per cuerda	Capital invested	Crop index	Yield of coffee per cuerda (pounds)	Farm income	Labor income
LESS THAN 200:									
Operated by the owner...	75	112	35	$11	$6,622	107	97	$85	$-445
Operated by owner and mayordomo.....	115	34	70	10	11,138	100	98	-167	-1,058
200 OR OVER:									
Operated by the owner...	360	27	139	7	25,228	100	96	258	-1,760
Operated by owner and mayordomo.....	373	48	190	9	32,338	108	107	376	-2,211
Operated by a manager...	423	3	242	15	45,550	157	166	-181	-3,825

EFFECT OF SIZE OF FARM AND LOCATION ON LABOR INCOME

The location of a farm is an important factor in most types of farm businesses. A farm located near a highway generally has considerable advantages over a farm located on a dirt road, chiefly because of the easy access to the farm and to near-by markets provided by the highway.

Of the farms of less than 200 *cuerdas* in size, 72 were located on highways, 27 on dirt roads, and 47 were off the road (table 27). The average capital invested in these farms was very much the same. The main differences between these small farms were in the gross returns per *cuerda*, crop index, farm income, and labor income. The farms on dirt roads had the highest labor income ($–365), while those on the highways had the lowest ($–658).

TABLE 27. RELATION OF SIZE OF FARM AND LOCATION TO LABOR INCOME AND OTHER FACTORS

224 COFFEE FARMS, PUERTO RICO, 1934

Size of farm (cuerdas)	Average size of farm (cuerdas)	Number of farms	Total cuerdas in coffee	Gross returns per cuerda (dollars)	Capital invested (dollars)	Crop index	Farm income (dollars)	Labor income (dollars)
LESS THAN 200:								
On highway	78	72	41	11	7,781	97	–36	–658
On dirt roads	77	27	33	14	6,894	122	187	–365
Off road	98	47	51	9	7,959	108	30	–607
200 OR OVER:								
On highway	359	31	161	7	29,492	90	–48	–2,407
On dirt roads	505	12	239	15	47,575	166	2,054	–1,752
Off road	335	35	163	8	25,281	102	37	–1,985

Of the farms of 200 or more *cuerdas* in size, 31 were on highways, 12 on dirt roads, and 35 off the road. The farms on dirt roads had again the highest labor income ($–1,752), while those on highways were again lowest ($–2,407). The dirt-road farms differed considerably from the other farms. Their size and number of *cuerdas* in coffee was much larger than for the other groups. The crop index was also higher, and the gross returns per *cuerda* about twice that of the other groups. These four factors, together, were directly responsible for the very high farm income ($2,054) in this group of farms. However, although this farm income appeared to be high, it was not sufficient to cover an 8 per cent interest on the average capital of $47,575, and thus a negative labor income resulted.

In general, this table indicated that, contrary to what would have been the general expectation, the best coffee farms, of those studied,

were not to be found along the highways. The only explanation with respect to this point is the fact that the highways are usually located along the lower sections of the coffee region in Puerto Rico, where the temperature and probably the soils are not so well adapted to coffee as they are in the higher sections. This accounted in part for the low crop indices obtained on the highway farms. The dirt-road farms had, in both cases, the highest crop indices.

EFFECT OF TOTAL CUERDAS IN COFFEE AND CROP INDEX ON LABOR INCOME

The relation between total *cuerdas* in coffee and labor income was already discussed in table 13. The object of table 28, however, was to show how this relation between total *cuerdas* in coffee and labor income was affected by different crop indices. For this purpose the farms were classified, on the basis of crop index, into three major groups: less than 75, 75 to 149, and 150 or more. Each of these groups was in turn sub-divided, according to total *cuerdas* in coffee into three minor groups: less than 50 *cuerdas*, 50 to 99, and 100 or more.

On each of the three major groups the labor income decreased, regardless of crop index, as the total *cuerdas* in coffee *increased*. This same relationship was observed in table 13. When the crop index was taken into consideration it was observed that labor income increased as the crop index for each minor group of farms increased. The larger farms, however, did not show this relationship so closely.

The group of small farms with a low crop index had an average labor income of $–530. That, with a medium crop index, increased its labor income to $–450. With a high crop index, the labor income was further increased to $–233.

The medium-sized farms showed a similar relationship. Those with a low crop index had an average labor income of $–1,120; with a medium crop index, it increased to $–998; and with a high crop index, the labor income again increased to $–333.

Large farms, with a low crop index, made a labor income of $–2,319. On those with a medium crop index the labor income decreased to $–2,504. With a high crop index, however, the labor income for the large farms increased considerably to $–1,666. This large increase indicated that the general tendency was for the large farms to show the same relationship as did the small and medium farms. Due to some reason, the second group of large farms failed to show such relationship.

TABLE 28. TOTAL CUERDAS IN COFFEE AND CROP INDEX IN RELATION TO LABOR INCOME AND OTHER FACTORS

224 COFFEE FARMS, PUERTO RICO, 1934

Total cuerdas in coffee	Number of farms	Average cuerdas in coffee	Average crop index	Gross returns per cuerda (dollars)	Yield of coffee per cuerda (pounds)	Cuerdas in crops per man equivalent	Labor income (dollars)
FARMS WITH A CROP INDEX OF LESS THAN 75:							
Less than 50 cuerdas	29	30	47	7	40	13.1	-530
50—99	24	76	54	6	48	17.2	-1,120
100 or more	25	172	51	6	49	18.3	-2,319
FARMS WITH A CROP INDEX OF 75 TO 149:							
Less than 50 cuerdas	47	23	105	12	104	8.3	-450
50—99	21	67	109	9	93	12.3	-998
100 or more	30	201	105	9	95	15.5	-2,504
FARMS WITH A CROP INDEX OF 150 OR MORE:							
Less than 50 cuerdas	25	21	200	17	196	7.8	-233
50—99	8	66	174	12	157	12.7	-333
100 or more	15	220	200	15	205	13.2	-1,666

EFFECT ON LABOR INCOME OF HAVING DIFFERENT FACTORS ABOVE THE AVERAGE

The effect on labor income of having different factors above the average is shown in table 29. It has already been demonstrated in preceding tables that during 1934 not all of the factors showed the same relation to labor income. Some were directly, while others indirectly related to labor income.

TABLE 29. EFECT ON LABOR INCOME OF HAVING DIFFERENT FACTORS ABOVE AVERAGE

224 COFFEE FARMS, PUERTO RICO, 1934

	Number of farms	Labor income
Average for all farms	224	$-1,120
AT LEAST ONE FACTOR ABOVE AVERAGE:		
Capital invested	72	-2,273
Total cuerdas in coffee	81	-2,128
Cuerdas in crops per man equivalent	104	-1,402
Labor costs per cuerda in crops	95	-1,312
Yield of coffee per cuerda	90	-857
Crop index	88	-791
Gross returns per cuerda	84	-691
AT LEAST TWO FACTORS ABOVE AVERAGE:		
Total cuerdas in coffee and capital invested	61	-2,470
Total cuerdas in coffee and gross returns per cuerda	25	-1,587
Cuerdas in crops per man equivalent and yield of coffee per cuerda	27	-1,196
Labor costs per cuerda in crops and gross returns per cuerda	48	-992
Crop index and yield of coffee per cuerda	74	-717
Crop index and gross returns per cuerda	54	-607
Total cuerdas in coffee and crop index	12	-590
AT LEAST THREE FACTORS ABOVE AVERAGE:		
Capital invested; total cuerdas in coffee; and labor costs per cuerda in crops	25	-2,882
Crop index; gross returns per cuerda; and yield of coffee per cuerda	48	-529
Total cuerdas in coffee; crop index; and gross returns per cuerda	9	-487

The average labor income on those farms having at least one factor above average ranged from $–2,273 to $–691. On those farms with at least two factors above average it varied from $–2,470 to $–590. On the farms with at least three factors above average the labor income also showed considerable variation, ranging from $–2,882 to $–487. It is, therefore, apparent that a farmer in order to increase his profits or reduce his losses should have a suitable combination of factors above the average.

Summary

This farm management study consisted of 224 coffee farms in Puerto Rico. The study was conducted by the Division of Agricultural Economics of the Puerto Rico Agricultural Experiment Station during 1935, and covered the calendar year 1934.

The average size of the farms was 186 *cuerdas,* with 88.5 *cuerdas* in coffee. Forty-two per cent of the coffee bushes were still under bearing age.

There was an average investment of $15,580 per farm. The value of land alone constituted 83.4 per cent of the investment.

All of the farms studied were still in a period of reconstruction, following the effects of the 1928 and 1932 hurricanes.

The average labor income on these farms was $–1,120 during 1934. Only 9 per cent of the farmers made positive labor incomes, averaging $414 per farm. Seven farmers made labor incomes of $500 or more.

Labor income showed an indirect relationship with all measures of size of business, and a direct relationship with the measures of efficiency of operation. In none of the tables included in this study was a positive labor income obtained for any of the groups of farms.

Farms operated by the owners themselves did not lose as much money as those operated either by the owner and a *mayordomo* or by salaried managers.

Farms located on dirt roads made better labor incomes than those located either on highways or off the roads.

Every coflee farmer in Puerto Rico should compare his farm with the averages given in table 13, and try to make his farm better than average in every point, particularly those in which it falls below the average.

THE MEXICAN COTTON BOLL WEEVIL, *ANTHONOMUS GRANDIS* BOHEMAN, IN HAITI

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Republique d'Haiti.

The known distribution of the Mexican cotton boll weevil, *Anthonomus grandis* Boheman, until recently has been the southeastern United States and the cotton-growing regions of both the Pacific and Gulf coasts of Mexico, but not including the central plateau known as the Laguna district, nor the eastern and central part of Yucatan. Only a few authentic records are known of its presence in Central America. It has several times been recorded from the Island of Cuba in the West Indies, but its scarcity there is due to the fact that cotton is not a commercial crop, and even the wild cotton may at times be so completely destroyed temporarily by hurricanes that over large areas the insect may cease to exist for a series of years. In such areas, cotton is at times commercially grown without being attacked by the weevil, but, possibly due to the later appearance of this pest or more probably to economic factors and the inertia favoring other crops, has never succeeded in becoming permanently established. The presence of the boll weevil is indeed mainly of importance, not in Cuba itself, but in constituting a threat to the nearest large island to the east, Hispaniola, where cotton is extensively grown and has long been one of the major exports from the Republic of Haiti. At its narrowest point, between Punta Maisí of eastern Cuba and Cap du Mole of northwestern Haiti, the Windward Passage is only fifty miles wide, but, so far as known, the boll weevil has never by its own efforts bridged this gap in sufficient numbers to become established in Haiti.

It is supposed that *Anthonomus grandis* was introduced by accident into Haiti, probably in the personal effects of returned emigrants from Cuba, or in commerce by boat from Texas, about 1932. It is most curious that it was found at this time near two ports, Jacmel in the south of Haiti, and Gonaives in the west, neither of which is near Cuba. The first indication of its presence was the unusual number of fallen squares noted for the crop of 1932–33 by cotton growers close to Jacmel, but the loss was not sufficiently severe to cause alarm at that time. During the season 1933–34, the infesta-

tions had spread to the regions around Gosseline, Lafond, Meyer and Cayes–Jacmel itself, but the intensity of the infestation was so light as to attract little attention from the growers. By the end of January 1935, however, the crop was a complete loss in the Jacmel region. Typical was the loss of Monsieur Désenclos, from a normal yield of 50,000 lbs. of cotton, to a low of 300 lbs. in that year. MM. Barreau and Valvil, of Carrefour Fauché, lost their entire crop.

A general survey made at the beginning of the year 1935 showed that the weevil was close to Port-au-Prince, at Bolosse, Bourdon, etc. All the area between Port-au-Prince and Grand Goâve was infested, as well as the entire plain of Gonaives from Savanne Désolée to Ennery. Towards the end of the crop, in May and June, the dispersion had reached Petionville and the road from Frère, and in the Department of the South had reached Carrefour Desruisseaux near Miragoâne.

By June 1935, the boll weevil had become established to the north and east of Port-au-Prince, and before the end of the harvest it had reached the neighborhood of l'Arcahaie and the lower slopes of Morne á Cabrits. In the Département du Sud, the Plaine d'Aquin became so completely infested that, altho at that time the entire region around Cayes was still not infested, for quarantine purposes it was considered so, and the restrictions, which had greatly hampered commercial traffic in and out of this region, were removed.

Up to the present time, the regions of Saint-Marc and of the Plateau Central have remained free from the pest, under the protection of a very severe quarantine. It has been found also, that in the Plaine de Cul de Sac, the trade winds blowing from Petionville and Ganthier towards the west tend to carry out to sea any weevils in flight, thus protecting, to some extent, the region to the north. But while the Plateau Central is in addition protected by zones where cotton does not grow, the Savane Diane and the Morne á Cabrits being thus in little danger of infestation by natural spread of the weevil, there are many chances that the region of Saint-Marc will become infested in the near future because of the great amount of traffic between l'Arcahaie and Saint-Marc. Its natural spread would otherwise be hindered by the relatively arid zone of Magazins Carriès.

If the region of Saint-Marc, as is to be feared, becomes infested this year, a special watch should be kept to retard the entrance of

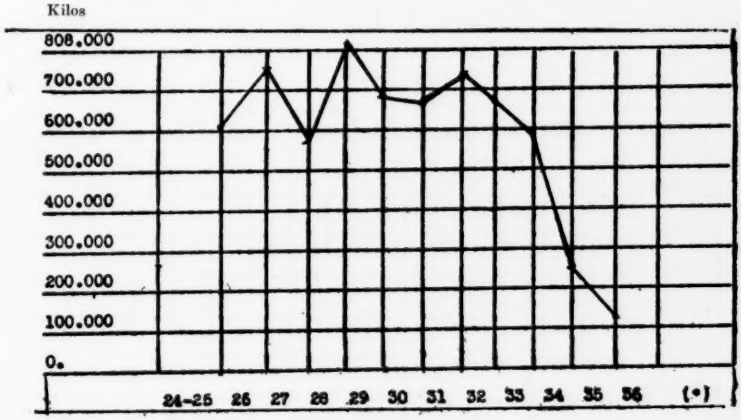
the weevil into the Plateau by the Vallee de l'Artibonite (Les Verrettes, la Chapelle and Mirebelais).

Extent of Losses

The records kept at the port of Jacmel facilitate a study of the losses suffered since the appearance of the boll weevil, as only the cotton grown in the immediate vicinity of Jacmel is exported from this port, and the region is entirely infested except at Cotes de Fer, of which the production is divided between Cayes, Petit Goâve and Jacmel.

Table No. 1

EXPORTATION OF COTTON FROM JACMEL, 1924 TO 1936



(*) From October to June 30, 1936.

Before the appearance of the boll weevil, the average exportation of cotton from Jacmel was 639,469 kgrs., the average of nine years. Because of the efforts of the Service Technique de l'Agriculture, and due to the encouragement of a good price, in 1931–32 the production increased to 740,890 kgrs., and in 1932–33 (the year in which the weevil is supposed to have been introduced, but before it had begun to attract attention or do much damage) the production was still above the average, or 670,013 kgrs. By 1933–34, this had decreased to 481,091 kgrs., in 1934–35 to 238,074 kgrs. In 1935–36, the production has again been halved, to 116,381 kgrs.

Considering 0.15 gourdes ($.03 in U. S. Currency) as the minimum price per pound of raw cotton, and taking the nine year aver-

age as the normal production from Jacmel (639,469 kgrs. = 4,000,000 pounds), the losses may be listed as follows:

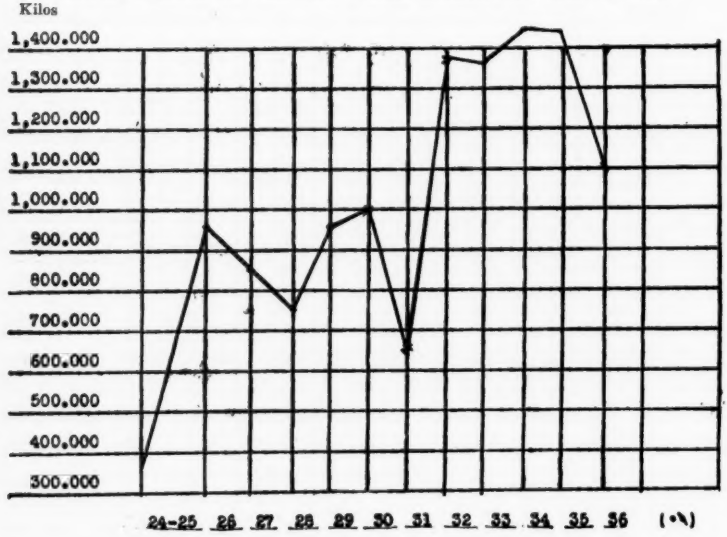
1933–34—1,100,000 lbs. of raw cotton, valued at	165,000 gdes.
1934–35—2,500,000 lbs. of raw cotton, valued at	375,000 gdes.
1935–36—3,200,000 lbs. of raw cotton, valued at	480,000 gdes.
	1,020,000 gdes.

This is an average of more than 300,000 gdes. ($60,000 in U. S. currency) a year lost by the cotton growers of the region of Jacmel, without taking into consideration the losses of the exporters and all others interested in the cotton trade at this port.

The records available for Gonaives do not show so clearly the extent of the damage caused by the boll weevil around this port because it also exports a large part of the cotton from the Plateau Central, where the area planted has greatly increased in recent years.

Table No. 2

EXPORTATION OF COTTON FROM GONAIVES, 1924 TO 1936



(*) From October to June 30, 1936.

Nevertheless, the above curve shows that, in spite of the great impulse recently given to the growing of cotton, production has remained stationary, even slightly decreasing in 1934–35. The de-

crease in production seems likely to become more significant this year, since from October to June, 1936, the exportation has been only 1,136,069 kgrs., while during the same period last year 1,392,810 kgrs. had been exported, a decrease of about 9 per cent.

This year, for the period October to June, Port-au-Prince and even Saint-Marc show similar decreases in production:

	Saint-Marc	Port-au-Prince
1934-35	2,350,778 kgrs.	1,603,112 kgrs.
1935-36	2,116,144 kgrs.	1,487,255 kgrs.
	A decrease of 9%	A decrease of 9%

Such is the present situation, with little promise for the future. It is certain that as long as the entrance of the boll weevil into the region of l'Artibonite and the Plateau Central can be retarded, and especially if at the same time the area planted to cotton in that region is increased, the effect of the boll weevil on total production of Haiti will not at once be noticeable. But if Saint-Marc, which exports 40 per cent of the total production of the Republic, and the Plateau Central, whose production is 20 per cent of the total crop, become infested to the same extent as Jacmel the total production of the Republic will be sharply and permanently decreased. It is absolutely certain that the boll weevil is not a temporary pest, which we can hope to get rid of in the future. It will be impossible to eradicate the weevil now that it is so firmly established here. The problem is not how to get rid of the boll weevil, but how we can maintain cotton production despite its presence.

The question is at once raised whether it is possible to maintain cotton production at the present level with the native perennial type of cotton and present methods of growing the crop. Is it possible for the ordinary farmers (who produce more than three-fourths of the total crop) with their limited means, to increase the production of their farms to compensate for the destruction caused by the boll weevil? Or can the farmers be induced to increase the area devoted to the production of cotton so that from more plants they obtain the same total yield as before the appearance of the weevil? Judging by the attitude of the farmers who lost their crop last year from boll weevil, it seems most probable that very few ordinary farmers will either have the means to increase the yield or feel sufficient incentive to increase the area under cultivation.

Is cotton growing then to be abandoned in Haiti, and if so, what other crop can take its place? It is certain that if a crop could be found, capable of giving the same financial returns as cotton in less

than five years, in the semi-arid soils known as "cotton soils", it would be wise to make the change. That being uncertain however, and considering the general dislike of farmers for new crops, the desirability of substituting an annual, short-season type of cotton for the perennial type now grown has been suggested.

In its relations to the boll weevil, the Haitian type of perennial cotton has a number of disadvantages. Being a perennial type of cotton, it furnishes fresh green leaves for the nourishment of adult weevils during almost the entire year. Furthermore, its large size and abundant foliage so completely shades the ground that the immature stages of the weevil in fallen squares and bolls are not killed by the heat of the sun on the bare ground between the rows as in the case of other kinds of cotton. Altho the production of squares is largely confined to two months, yet a sufficient number of squares are produced before and after this period to furnish a much longer possible period of reproduction for the weevil than in the case of the strains of American upland cotton especially selected for short season. An additional disadvantage, having nothing to do with the boll weevil, is its low yield, only a "millier" (one thousand pounds) of raw cotton per hectare under very good conditions.

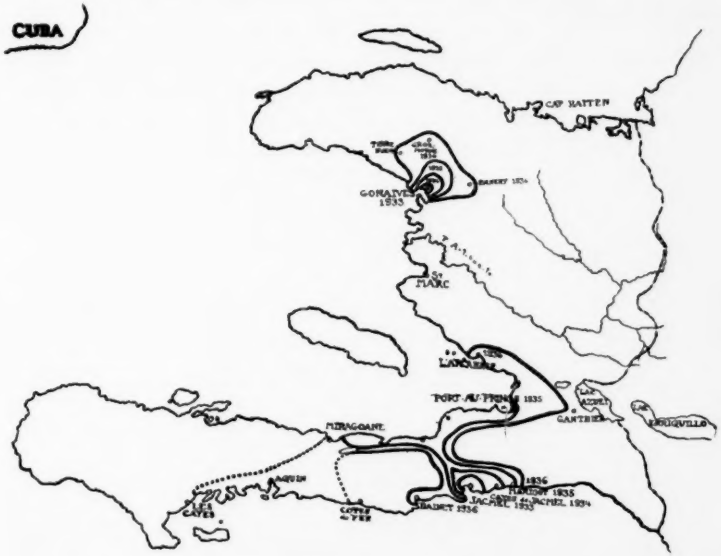
On the other hand, the native Haitian type of perennial cotton has certain unique advantages making it peculiarly suitable to Haitian conditions, at least up to the present. Foremost among its advantages is a resistance to the attack of the pink bollworm so marked that the commercial damage caused by this pest since its appearance in 1925 is negligible. When grown in experimental plots beside many other kinds of cotton, this resistance to pink bollworm attack is very marked, but when grown commercially in the absence of other varieties, the pink bollworm practically ceases to exist. During the beginning of the crop, rarely can more than one or two infested bolls be found in several hour's search, and even at the very end of the picking season, infestation is normally not more than 1 or 2 per cent, too little to be noted by either grower or exporter.

The Haitian farmer is used to the perennial type of cotton. It is not necessary to plant every year, and the same plants yield for several years, even if not cut back to the ground at the end of the picking season. Practically the only expense of growing cotton in Haiti is harvesting the crop and transporting to market, making the expense of production so low that even the small return on account of inferior quality and low yield nets the farmer an excellent profit. At present, that profit seems about to be eliminated by the boll weevil, but if the parallel of the pink bollworm is any criterium, the

appearance of this new pest may merely serve to eliminate the strains of native cotton most susceptible to its attack, just as the advent of the pink bollworm eliminated the foreign strains of Brazilian Kidney, Meade and other imported varieties mingled at that time with the Haitian perennial cotton.

Explanation of Map

The outline map of the Republic of Haiti is taken from the "Carte publiée par les Fréres de l'Instruction Chrétienne avec approbation du Département de l'Instruction Publique par sa letter en date du 9 Octobre 1931".



Haiti is the western part of the Island of Hispaniola, in the West Indies; the eastern part being the Republic of Santo Domingo. To the northwest is the Island of Cuba, fifty miles away; to the southwest is the Island of Jamaica, too far away to be shown.

The lines marking the dispersion of the boll weevil in Haiti were determined by the authors for the years as noted on the map itself.

The high mountain range which forms the southern peninsula of Haiti, locally "Presque Isle", is connected with the remainder of the island by the Plaine de Cul-de-Sac, only a few feet above sea leavel north of Port-au-Prince, and considerably below sea level at

the lagoons of Lac Abuei and Lac Enriquillo. This mountain range is sufficiently broken north of Jacmel to permit passage of a road, and it is along this road that the boll weevil gained access to the northern plain of Presque Isle. After becoming established north of the mountain range, it spread east to Port-au-Prince (1935) and l'Arcahaie (1936), and to the west to Miragoane (1935) and south across the mountains along the road to Aquin and Les Cayes.

The spread of the boll weevil from Gonaives (1933) is presumably determined by the prevailing winds from the southeast, keeping it out of the Plaine de l'Artibonite, and carrying it northwest to Terre Nueve (1936), while commerce is largely responsible for its spread along the road east to Ennery (1936) and north to Gros-Morne (1936).

THE DEVELOPMENT OF THE GIANT SURINAM TOAD, *BUFO MARINUS* L.

By FRANCISCO SEÍN, JR., *Assistant Entomologist*, Agricultural Experiment Station, Río Piedras, P. R.

On April 20, 1934, a strand of the eggs of the giant Surinam toad, *Bufo marinus* L., was collected in a brook at Monacillos, Río Piedras, Puerto Rico. The strand was found dangling from grass stems in swiftly running water, where it presumably had been carried by the current before becoming entangled in the grass. It was carried to the laboratory and placed in a large receptacle of water, where all changes could be readily observed. (Fig. 1.) The strand was transparent, with segmentation visible at the tips. The black, rounded eggs were embedded in the center of this strand.

On April 21, 1934, the eggs hatched, each tadpole pushing its way out of the main strand into branches or short lateral tubes. (Fig. 2, A and B.) The tadpoles later in the day left the branch tubes but remained attached to them externally. (Fig. 2, C.)

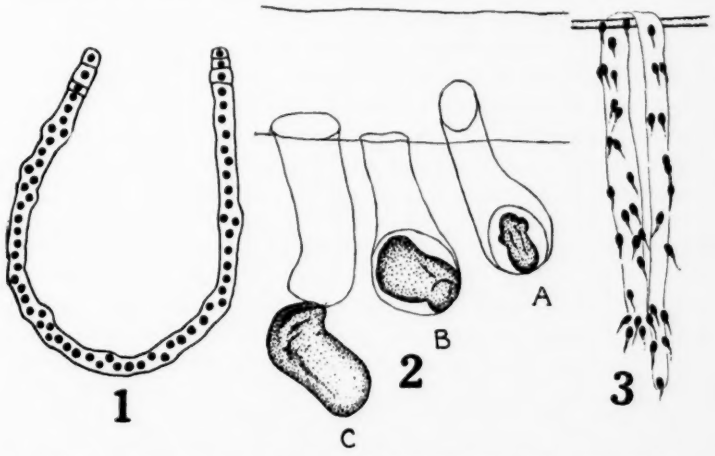


FIG. 1. Strand of eggs of the giant Surinam toad, *Bufo marinus* L.

FIG. 2. A section of the egg strand showing branches or lateral tubes. (A) and (B), the tadpoles still inside the tubes; (C), the tadpole outside the tube.

FIG. 3. The tadpoles with well developed tails clinging to the outside of the egg strand.

By April 23d, practically all of the tadpoles had become rounded and had developed tails, but they still remained attached to the egg-strand. (Fig. 3.) Shortly afterwards they abandoned it, dropping to the bottom and sides of the glass receptacle. They were fed lettuce, bread crumbs and occasional insects or earthworms, which were killed and cut up in small pieces for them. They were extremely fond of the earthworms and the bread. Large numbers of them feeding on a floating piece of bread would often cause it to slowly revolve, as it was pushed around by eager wagging of their tails.

By June 11th several tadpoles had developed hind legs, and by the 20th, two individuals had developed fore legs. One of these still had a complete tail, but the tail of the other had already begun to shrink and curve downwards between its hind legs. By the next day, the tail had become a stump and the toad left the water, being at that time only one-quarter of an inch long. From time to time during the summer, others became adult, but no record was kept, and food was supplied more sparingly.

On October 3d, 1934, the last tadpole had transformed to adult, nearly six months after the eggs were collected.

WHAT THE GIANT SURINAM TOAD, *BUFO MARINUS* L., IS EATING NOW IN PUERTO RICO

By GEORGE N. WOLCOTT, *Entomologist*, Agricultural Experiment Station, Río Piedras, P. R.

In the history of man's attempts to control pests by the introduction of some other animal to attack and destroy them are numerous instances of the later development of less desirable or injurious habits by the introduced animal after the numbers of the pest on which it is normally supposed to feed have been greatly reduced, and its shrinking supply of food must be augmented by the substitution of other items, neutral or even beneficial to man, if it is to continue to exist in large numbers. Such an eventual result has been predicted in the case of the giant Surinam toad, *Bufo marinus* L., in Puerto Rico.

Originally introduced in 1920 and 1924 to control white grubs in cane fields, it proved so extraordinarily successful within the next ten years, because of its decided preference for the adults (May beetles, or "caculos") of the white grubs, that they have now ceased to be of appreciable economic importance in all the more level coastal regions where cane is most extensively grown (3). It might possibly be expected that the toads, deprived of their main source of food and forced to find new sources or perish, would have already begun to be a much less desirable permanent addition to the fauna of the Island than when engaged in the elimination of the white grub pest. Their present status indicates, however, that such fears were quite unfounded. Altho not susceptible to statistical proof, it is a matter of common observation that toads are much less abundant now than a few years ago.

One possible contributing cause to their present comparative scarcity is that some insects or other animals already present in Puerto Rico before the importation of the toad, and of course quite unaccustomed to feed upon it or affect it in any way, have gradually learned to attack it. One such striking instance is the large number of predaceous diving beetle larvae (Dytiscidae), *Megadytes giganteus* Castelnau, as determined by Dr. S. E. Danforth, which have been noted developing recently in a pool only a few weeks previously well stocked with tadpoles of *Bufo marinus*. Presumably the fundamental cause of the scarcity of the toads, however, is lack of food, which may either prevent normal reproduction, or cause actual star-

vation of toads unable to change their habits and develop a broader basis of nourishment.

For determining whether the Surinam toad has changed its food habits in the last few years, the investigations conducted by Mrs. Raquel R. Dexter (1) in 1931, when the toad had presumably attained its maximum abundance in Puerto Rico, are most useful. She collected three hundred toads from eighteen localities, all of them in the lowlands or cane-producing sections of the Island, where the toads were very abundant at that time. The data given by her are based on stomach contents examinations, and are expressed in percentage of the total bulk of the food there found. Scarabaeid beetles, the adults of white grubs (neutral and non-injurious species, as well as the economic pests) she found to constitute 43.3 per cent of the total food of the toad at that time; millipeds one-fourth of the total, Curculionid weevils one-sixth and mole-crickets or "changas" only one-fortieth. The Scoliid wasp, *Campsomeris dorsata* F., a parasite on the larvae of the rough black Scarabaeid beetle, *Ligyrus tumulosus* Burmeister, was found to constitute 5.1 per cent of the food of the toad, while the host beetle adult was 12.0 per cent of the toad's food. Such intensive consumption of these two insects, host and parasite, could not fail to produce decisive results in lessening their numbers, an eventuality which was reported by the present writer (2) in 1934. The *Ligyrus* grubs are strictly saprophytic, and neutral in their relations to the interests of man, but those of the yellow-brown May beetles are the white grubs which were such serious pests of sugar-cane and other crops. Their adults formed over one-quarter of the food of the toad, and the result soon became obvious to every cane-grower on the Island. Millipeds are most common in well-rotted manure or compost heaps, or in old malojillo grass, and are of so little direct importance to man that not even estimates of their abundance are available. One of their most annoying habits was to crawl over the concrete porch of a house at the Experiment Station in such numbers during wet weather that no sooner were they swept away at one end than an equal number had already appeared at the other. This no longer occurs, and while millipeds can still be found in abundance in suitable locations, they seem much less numerous generally. Of all the important items in the food of the toad as noted by Mrs. Dexter in 1931, only the common Otiorhynchid weevils or "vaquitas", seem to have decreased slightly, if at all, since that time.

The toads themselves are so much less numerous than formerly that considerably numbers can be observed only in the most favorable locations. A small, sluggish brook runs thru the grounds of the Agricultural Experiment Station at Rio Piedras, and on one side a considerable expanse of well-kept lawn rises in gentle slope. Even one casually crossing the lawn in the daytime will often note pellets of toad excrement on it, especially after two or three rainy nights when the toads have been active. An examination of these pellets gives by no means as exact a record of the food habits of the toad as would stomach examinations, for some items may be so lightly chitinized as to be completely digested. But so many of the normal items of the toad's food are heavily chitinized that their undigested remains in the excrement pellets may be taken as a reasonably accurate indication of the bulk of the food. The results of the examinations can not be expressed as bulk percentages, but only as numbers of the insects found. The first collections, made over a year ago at Rio Piedras, were few in number, and at the time little regarded, but when compared with the much more numerous collections of this spring are seen to be surprisingly similar. It should be noted, however, that these observations were confined to a single restricted locality, and that a somewhat wider range of food might be expected if examinations were made from more localities, and at other times of year.

Table No. 1.

The Contents of the Pellets of Excrement of the Giant Surinam Toad, *Bufo marinus* L., at Rio Piedras, Puerto Rico, 1935–36.

14 pellets, May 9, 1935, contained:

36 black Scarabeid beetles, *Parachalepus (Dyscinetus) barbatus* F.
3 large brown May beetles, *Phyllophaga (Lachnosterna) portoricensis* Smyth
2 cucubanos, *Pyrophorus luminosus* Illiger
1 cockroach, *Periplaneta americana* L.
1 stone

5 pellets, Sept.–Oct., 1935, contained:

21 black Scarabeid beetles, *Parachalepsus (Dyscinetus) barbatus* F.
4 common Otiorhynchid weevils, or "vaquitas", *Diapreps abbreviatus* L.
1 large brown May beetle, *Phyllophaga (Lachnosterna) portoricensis* Smyth
1 blade of grass

58 pelelts, April 23–28, 1936, contained:

118 black Scarabaeid beetles, *Parachalepsus (Dyscinetus) barbatus* F.
195 large brown May beetles, *Phyllophaga (Lachnosterna) portoricensis* Smyth
6 small brown May beetles, *Phyllophaga (Lachnosterna) citri* Smyth
1 rough black Scarabaeid beetle, *Ligyrus tumulosus* Burmeister
1 common Otiorynchid weevil, or "vaquita", *Diaprepes abbreviatus* L.
4 leaves
2 stones
1 seed

12 pellets, collected September 14, 1936, contained:

54 black Scarabaeid beetles, *Parachalepus (Dyscinetus) barbatus* F.
2 large brown May beetles, *Phyllophaga (Lachnosterna) portoricensis* Smyth
3 common large Otiorhynchid weevils, *Diapreps abbreviatus* L.
1 large bee ??
1 cockroach, near *Pycnoscelus*
1 large Pentatomid bug, *Nezara viridula* L.
1 large scorpion
1 milliped
grass
vegetable fiber
mud

1 pellet, collected September 20, 1936, at Loíza Aldea, in field of young plant cane where changa tunnels were abundant, contained:

2 large brown May beetles, *Phyllophaga (Lachnosterna) portoricensis* Smyth
4 common large Otiorhynchid beetles, *Diaprepes abbreviatus* L.

1 pellet, collected October 20, 1936, at Central San Vicente, Vega Baja, in field of young ratoon cane, "poyal" land, contained:

5 rotten cane stalk weevils, *Metamasius hemipterus* L.
2 common large Otiorhynchid beetles, *Diaprepes abbreviatus* L.
1 large dark green Cicindelid beetle, *Tetracha sobrina infuscata* Mann.
2 millipeds

For instance, the rough black Scarabaeid, *Ligyrus tumulosus* Burmeister, occurs normally in sandy land, and in sandy localities doubtless still forms an important item in the food of the toad, together with its wasp parasite, *Campsomeris dorsata* F. On the other

hand, it is quite inexplicable that of the two common small black Scarabaeid beetles; *Parachalepus* (*Dyscinetus*) *barbatus* F. and *Dyscinetus picipes* Burmeister (= *D. trachypygus* Burmeister), only one of the latter should be found eaten by the toads in Río Piedras in 1935–36, for in past years collections (by entomologists) of both species in abundance have been made there as well as in other parts of the Island.

The inclusion of stones and vegetable matter in the excrement of the toads was probably accidental, and incidental in obtaining the living items in their food. The absence of millipeds is possibly due to local scarcity on the lawn, for a single pellet examined in August 1936, picked up from beside a compost heap containing millipeds, was found to contain nothing else but their remains and earth. Of the insects other than the Scarabaeid beetles, it is a matter of common observation, and great regret, that the cucubano, *Pyrophorus luminosus* Illiger, is so much less common now at Río Piedras than it was before the introduction of the toad. In the mountains of Puerto Rico, where toads are noticeably scarce, the cucubano seems to be quite as abundant as it ever was. Thus it would appear that the cucubano continues to occur in normal abundance in the mountains because of the permanent scarcity of the toad there, while in the moist lowlands it barely manages to survive. The scarcity of the common Otiorhynchid weevil, or "vaquita", *Diaprepes abbreviatus* L., in the pellets of toad excrement examined is accidental, and possibly due to a temporary scarcity of the adults at the time the pellets were collected, for the insect still seems very abundant, and despite its normally aerial and diurnal habits, in previous years was an important item in the food of the toad.

It would thus appear that, while no decided change in the food habits of the toad has occurred in recent years due to the increasing scarcity of May beetles, the even greater scarcity of some of the other insects and other animals previously eaten makes the trend towards an even more exclusive selection of the adults of white grubs for its food. Such a statement seems hardly logical, yet the data point to no other conclusion. It indicates that the introduction of *Bufo marinus* into Puerto Rico for the control of white grubs was not only an immediate and temporary success, but tends, at least so far as the food habits of the toad determine its trend, continually to become more effective and more permanent.

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THE ORGANISM CAUSING THE DRY TOP ROT OF SUGAR CANE

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This organism and the disease caused by it are very interesting because they were not known outside of Puerto Rico * for several years following their discovery and because of the problem involved in the taxonomy of the organism.

Matz (**10**) published the first description of the organism in 1920 under the name of *Plasmodiophora vascularum*. Two years later he published a second paper (**11**) in which he gave additional data.

Some doubt was expressed as to the taxonomic position of the organism which led the writer to make a study (**1**) which resulted in the transfer of the organism to the genus *Ligniera*. This was questioned by several workers and especially by Dr. W. R. Ivimey Cook of the University of Bristol, England, who started a correspondence with the author. Finally the author sent a collection of material to Dr. Cook of Bristol for study. As a result of these studies Dr. Cook decided that the disease was due to Rhizopods and prepared a paper (**6**) in which he described a new genus and two species, *Amoebosporus vascularum* and *A. saccharinum*. The writer disagreed with Dr. W. R. Ivimey Cook and immediately started a series of studies which have been continued to the present time. The results of these studies are recorded in this paper. In these studies the writer has examined a very large amount of material, fresh and in micro-preparations. All stages in the development of the organism are found without difficulty except the germination of the spores and the zoospore stages. However, sufficient material showing these stages was found to satisfy the writer that there is but one organism and that it does not belong to *Plasmodiophora* or to the *Protozoa*.

The organism passes into the new shoots of the cane as a plasmodium. This was demonstrated in fresh material from the field and in plants grown in pots in the green house and in water in glass cylinders in the laboratory. No stage other than the plasmodium

* It was found in Venezuela a few years ago. Probably introduced from Puerto Rico.

was found in these young shoots and this plasmodium was always in the tracheary tubes. In the older canes it could be found in the other cells. The writer failed to find any nuclei in this plasmodium until the formation of the spores as described in the first paper (1). The nuclei appear with the formation of the spores (Figs. 1, 2 and 3) and have very much the same appearance as that stage of *Woronina polycystis* as figured by Cook and Nicholson in 1933 (8). These plasmodia in the older canes very frequently contain large bodies which the writer believes to be resting spores that have not germinated (Fig. 2). Dr. W. R. Ivimey Cook calls them empty cysts from which the spores have emerged. These resting spores or cysts can be found in great numbers and completely filling sections of the tracheary tubes. These large spores with very thick walls are to be found in the tracheary tubes (Figs. 8 x) and sometimes in the other cells (Figs. 8 *y* and 16). The writer has observed large zoospores in those resting spores (Fig. 6, *a*, *b*, *c*) but has never observed the formation of a large number of spores in them as described by Dr. W. R. Ivimey Cook.

The writer has observed many spores which were variable in size and to some extent in form in both tracheary tubes and in the surrounding cells (Figs. 8–20). Spores that are fairly uniform in size and shape may occupy certain cells while in other cases the spores in a cell or tracheary tube may be variable in size.

The cells, other than these in the tracheary tubes that contain either plasmodia or spores develop very thick walls (Figs. 8, 10, 13, 15 and 16). These spores appear to be the same as those which W. R. Ivimey Cook designated as cysts.

A careful study of the work of Matz, W. R. Ivimey Cook and the writer shows a very general agreement of some points but different interpretations. A comparison of all the studies by these three workers, including the data in this paper is as follows:

All have ageed that the organism lives in the fibro-vascular bundles. Matz states that it lives in the annular and spiral trachiedes and pitted vessels. The writer found the organism in the tracheary tubes, in the surrounding cells of the fibro-vascular bundle and sometimes in the parenchyma cells, especially in the older canes. In the very young canes it was confined to the tracheary tubes. W. R. Ivimey Cook reports *A. vascularum* in the spiral and annular tracheids and in the pitted vessels of the vascular bundles, and *A. saccharinum* in some of the cortical cells as well as in the phloem and xylem parenchyma but never in the xylem vessels.

Both Matz and the writer describe a plasmodium, while W. R. Ivimey Cook used the terms amoebae and amoeboid. Matz makes no mention of nuclei in the spores but his drawings show them. Both the Cooks state definitely that they failed to find nuclei in the spores. The writer has examined a large number of plasmodia (W. R. Ivimey Cook's amoeba) and failed to find any evidence of nuclei. However, as soon as the plasmodium begins to form spores the nuclei appear (Figs. 1 and 2).

Matz did not succeed in germinating the spores in sugar water, cane juice, in fermented cane juice or in several agars. The writer germinated many of the large spores, which W. R. Ivimey Cook called cysts in sterilized, distilled water.

The writer reported the formation of germ tubes in these old spores in his first paper but no evidence of swarm spores. In his later studies he found these resting spores or cysts could be germinated in sterilized distilled water. They were mounted in sterilized distilled water on slides and kept in moist chambers for one or more days. A few resting spores which had been kept in this manner showed a very slow internal movement as one large zoospore (Fig. 6 *a* and 6 *b*) sometimes moving in one direction and sometimes in the other. In one case a cell wall had been formed and two moving bodies were observed (fig. 6 *c*), one in each cell. In another case three walls were formed indicating a quadrant (Fig. 6 *d*) but there was no internal movement. These resting spores developed short germ tubes (Figs. 6 *e* and 7 *a*) by which the zoospores emerged but the writer did not observe the emergence of them. However, many empty spores with open germ tubes and a few free swimming zoospores were observed. The zoospores rotated very slowly and in the same manner as those that were confined to the resting spores (Fig. 7 *b*). No cilia could be seen with a high power, oil immersion lens. Several of these zoospores were studied and found to develop a very slowly moving amoeboid form (Fig 7 *c*). It is very evident to the writer that they represent this stage in the life history of the organism in the tracheary tubes of the host plant and that they unite to form the plasmodium. It is possible that zoospores in wet soil undergo the same transition. No nuclei were visible in this stage but the writer did not stain any of them.

A single flagellate spore was reported in the writer's first paper. It was in the tracheary tube in a prepared micro-section. No others have been observed by the writer. Dr. W. R. Ivimey Cook reported both amoeboid and flagellate stages. The writer did not

observe the formation of a large number of spores such as were described by Dr. W. R. Ivimey Cook but the studies of the latter were necessarily confined to dead material. Therefore, it was impossible for him to make any studies on germination.

Very large resting spores (W. R. Ivimey Cook's cysts) with thick walls are to be found in the tracheary tubes, sometimes filling them for a considerable distance (Fig. 8 *x*). They are sometimes found in other cells (Figs. 8 *y* and 16).

Matz reports that "sometimes these vessels were filled with a mass of granular protoplasm containing all stages between numerous, small, immature, ovate bodies of various sizes and the mature, spherical, larger spores". The writer found a variation in size and character of spores (Figs. 11 and 12) but believed them to be stages in the life history of a single organism. The results of the studies recorded in this paper support this opinion. Dr. W. R. Ivimey Cook believes them to be stages in the life history of the two different organism which he described. Matz does not mentioned nuclei in the spores but his drawings show them. Both Dr. W. R. Ivimey Cook and the writer found very definite nuclei.

The writer has observed many spores which were variable in size and to some extent in form in both tracheary tubes and in the surrounding cells (Figs. 8–20). Spores that are fairly uniform in size and shape may occupy certain cells while in other cases the spores in a cell or tracheary tube may be variable in size.

The spores, other than those in the tracheary tubes that contain either plasmodia or spores, develop very thick walls (Figs. 8, 10, 13, 15 and 16).

The plasmodia in the tracheary tubes and cells of other tissues had the same general appearance (Figs. 2 and 15). The large resting spores in the tracheary tubes and in other cells (Fig. 8) had the same general appearance and the writer does not believe that they were due to different organisms. Large and small spores were to be seen in the tracheary tubes (Figs. 10, 11, 12, 14 and 17) and in various other tissues (Figs. 10 and 13). The relationship of these large and small spores has not been established and the writer believes them to be stages of the one organism. If not, it is very evident that two parasites generally occupy the same cells at the same time.

W. R. Ivimey Cook writing of *A. vascularum* says:

"Germination of the spores is difficult to observe, and the author is not certain that the following stages form part of the same life-cycle. As far

as he can see the spores germinate to produce a small spherical body containing a clearly marked nucleus in which there is a vacuole associated with the nucleus. The protoplasm late becomes more vacuolated as the amoeba grows."

In writing of *A. saccharinum* he says:

"The amoeba finally became surrounded with a cyst wall and the contents divided up into a number of small spherical cells each of which contained a single nucleus. . . . Fixation must have occurred during the process, since, while some of the spores, remain within the cyst, others have left it. As far as could be made out these bodies are provided with an apical flagellum, and at this early stage are pyriform in shape, though later they became rounded."

Matz in his second paper discribed a division of spores into two, four and sometimes six parts. Dr. W. R. Ivimey Cook described a division in both his *Amoebosporium saccharinum* and his *A. vasculorum*. The writer found a stage that appeared to be a division of the nuclei (Figs. 3 and 4) but failed to follow a life history such as that described by Dr. W. R. Ivimey Cook. Dr. W. R. Ivimey Cook also speaks of the protoplasm surrounding the empty cysts which is apparently the same as shown in figure 2. In my first paper on this subject I described this as a spore which had failed to germinate. Since that time I have examined a large number and am inclined to adher to that view. I have never found any of these spores with an opening in the wall, unless a germ tube had been formed.

Dr. W. R. Ivimey Cook speaks of the division of the nucleus in these large spores and the formation of a number of small spores. I have not been able to confirm his views in either case. The nuclei stain readily until the spores are almost mature (Fig. 5) but it is practically impossible to stain them in old resting spores (Figs. 2 and 8).

Dr. W. R. Ivimey Cook states that his *Amoebosporum vascularum* is found in the spiral, annular and pitted vessels of the vascular bundles and that his *A. saccharinum* is found in some of the cortical cells as well as in the phloem and xylem parenchyma, but never in the xylem vessels.

I have found what I believe to be one species in both tracheary tubes and in the fibrous cells (Figs. 14, 15, 16) and sometimes in the parenchyma. Also, I have found small spores in both tracheary tubes and in the fibrous cells (Figs. 9, 20). Sometimes I find both the large and small spores in the same tracheary tubes (Figs. 10–12) and the same in the fibrous cells (Figs. 18–20). I believe them to be stages in the life history of a single organism. I cannot harmonize Dr. W. R. Ivimey Cook's results with my studies on the germination of the large spores. However, it should be remembered that Dr. W.

R. Ivimey Cook's studies have been restricted to the material which I sent to him while I had the advantage in that I studied fresh material throughout the year for several years.

One point which has not been mentioned in any of the previous papers is that when fibrous cells are inhabitated they always develop very thick walls, apparently the result of stimulation (Figs. 8–16).

Let us now turn our attention to the presence of this organism or organisms in the roots. Thus far my studies on this phase of the subject have been very limited but it is reasonable to suppose that the penetration is through the roots. This has not been observed but I have found the plasmodium in the roots, and Matz and the writer have found the spore stage.

Method of Infection

The method by which healthy plants become infected with this organism has not been definitely determined. Judging from the environmental conditions under which infections take place, the life history of the organism as traced in this paper and the life history of other organisms belonging to the Plasmodiophoraceae we are justified in believing that zoospores are formed and that they penetrate the roots of healthy canes. This has not been observed but Matz reported the finding of the organism in the roots of growing cane and the writer has found both the plasmodium and spores in the tracheary tubes of the roots.

The Taxonomic Position of the Fungus

The taxonomic relationship of this organism presents some rather interesting questions. My recent studies convince me that it does not belong to the Plasmodiophora or the Protozoa. It does not show nuclei in the plasmodium by any of the methods used. It is found mostly in the tracheary tubes and it does not cause hypertrophies.

It differs from the genus Sorosporaera in that it is not restricted to the roots but is most prominent in the stems and the spores are not collected into hollow masses.

It differs from the original description of the genus *Ligniera* in that it is not restricted to the roots but is most prominent in the stems but it resembles this genus in that it does not produce hypertrophies and in having the spores collected in masses.

The writer has made a careful study of the literature beginning with 1911 when Maire and Tison (**12**) erected the genus *Ligniera*. They said:

"The difference between the swellings produced by *Plasmodiophora Brassicae* and those produced by *Sorosphaera Veronicae* is that the cells of *Veronica* show towards the end some mitosis that are not accompanied with cell wall formation, while in the case of cabbage the formation of cell walls follows the mitosis to the end.

"The study of *Ligniera* throws a new light on the affinities of the *Plasmodiophoraceae*. The *Ligniera* are very similar to the *Rhizomyxa hypogae Borzi*, also a non hypertrophiating parasite of the roots of various plants. That Rhizomyxa, according to Borzi, (1884) is a complex of various organisms and certainly the Ligniera were included in the complex. One of the drawings of Borzi represents *L. verrucosa* (that apparently grows on *Trifolium resupinatum*); other drawings suggest *L. radicalis* and *L. junci*. However, the real *Rhizomyxa hypogae* within the narrow limits given by A. Fischer (1892), characterized by the presence of zoospores within the thin walls containing several zoospores, such zoospores are not present in the *Ligniera*. The *Ligniera* are similar to the *Woronina polycytis* Cornu, whose balls of kystes remind one of the balls of spores of the *L. verrucosa*. It is quite possible that the *Ligniera* are derived from organisms similar to the Woronina through the disappearance of the zoosporocytes. The original of the Plasmodiophoraceae might be looked for in the studies of the Chytridiales.

"Nemec (1911) just described a Chytridiales of the Woroniaceae group, the *Sorolpidium Beta*, (**13**), parasites on the roots of Beta. That Chytridiales show plasmodia similar to those of the Ligniera, real zoosporocytes very similar to those of the Rhizomyxa. One can observe mitoses of a type similar to those of Plasmodiophoraceae. The author confirms our opinion as to the origin of the Plasmodiopraceae. They seem to be different from the Woroniaceae through the disappearance of the zoosporocytes."

Maire and Tison included in this genus two species which they had described, *L. verrucosa* living in the roots of *Voronica arvensis* and *L. radicolis* living in the roots of *Callitriche stagnalis*. They also transferred *Sporosphora junci* to this genus because it caused little or no hypertrophy of the roots and because the spores were not arranged in any definite system. In the following year Winge (1912) transferred *Sorosphaera graminis* to this genus.

Schwartz (1914) published a paper (**16**) on the *Plasmodiophoraceae* and their relationship to Mycetozoa and Chytriadiae in which he recognized seven genera as follows; 1. *Plasmodiophora*, 2. *Sorosphaera*, 3. *Tetramyxa*, 4. *Sorodiscus*, 5. *Molliardia*, 6. *Spongospora* and 7. *Ligniera*. The first five cause hypertrophies; the last two do not. In plasmodiophora the spores are free: in *Sorosphaera* they are collected into hollow spheres; in Ligniera they are collected into masses of varying shapes (e. g. spheres and ellipsoides).

In his discussion of the genus *Ligniera* he says,—

"The genus which is closely allied to *Sorosphaera*, was formed by Maire and Tison to include these members of the Plasmodiophoraceae in which the spore

clusters are most usually ellipsoidal and irregular shaped and rarely spherical. A common characteristic of the members of this genus is that they do not give rise either to hypertrophy of tissue or to nuclear degeneration in the host plant."

He also says that all the species of this genus are root parasites living in the outer cortex and that the infection is through the root hairs.

W. R. Ivimey Cook (1926) published a paper on the genus Ligniera (**2**) in which he repeated the description of the genus as given by Maire and Tison which is as follows:

"In cellulis hospitis immutatis parasitans: nec tumores gignons; schizogina reducta; sporae in acervales variforme conjunctae."

He says,—

"The full grown amoeba may be compared with the plasmodium of the Mycetozoa, which it resembles very closely. The size of the full-grown amoeba is usually limited by the size of the host cell, though if this cell is very large the contents may become exhausted before the amoeba has completely filled it."

In the summary of this paper he says,—

"The genus *Ligniera* is a member of the plasmodiophoraceae, and has many points of relationship with the Mycetozoa. It differs from any other member of the group in not causing any hypertrophy of the host tissue."

In 1928 Dr. W. R. Ivimey Cook (**3**) published a paper on the Methods of Nuclear Division in the Plasmodiophorales in which he said,—

"The Plasmodiophorales show a great similarity to the Amoeba in their methods of nuclear division. They show some similarity to the Mycetozoa in their life-history. It is considered probable that the two groups have originated from a common ancestor in the evolutionary series from Protomyxa to the Lobosa. Owing the presence of Protomitosis it is considered that the Plasmodiophorales have become separated before the Mycetozoa were. There is no common grounds for considering that the Plasmodiophorales and Chytridiales are closely related; the position of the *Soroledipium betae* does not support such an assumption."

Cook and Schewartz (1929) in their paper (**4**) on *Sorosphaera radicale* said,—

"These zoospores however, bear a close resemblance to those previously observed in *Ligniera junci* and those described by other workers in the genera *Spongospora* and *Plasmodiophora.*

"It is the structure of the spore mass which renders this species easily distinguished from any previously described. In *L. junci* and *L. verrucosa* which have been known to attack grass roots the spores are not arranged in

any definite system, though at times they appear to be grouped in a more or less spherical mass. In the genus Sorosphaera, of which only *S. verronicae* has been described, the spores are arranged in a hollow sphere.''

W. R. Ivimey Cook (1930) in a paper (**5**) on *Plasmodiophora brassicae* referred to the transfer of this species from *Plasmodiophora* to *Ligniera* by the writer of this paper and said,—

''Cook prefers to place the organism in the genus *Ligniera*, because it does not cause hypertrophy of the host tissues, but in our opinion (based on the two accounts which we have read) there is very little ground on which to refer it to either genus.''

W. R. Ivimey Cook (1933) published ''A monograph of the Plasmodiophorales'' (**7**) in which he recognizes six genera: (1) *Plasmodiophora*, (2) *Sorosphaera*, (3) *Sorodiscus*, (4) *Spongospora*, (5) *Tetramyxa* and (6) *Ligniera*. In his key the first five form a group and *Ligniera* is separated but in his diagram showing the phylogeny it is placed as an offshoot or branch of Plasmodiophora. In his discussion of this genus he says that Fitzpatrick ''fails to recognize the difference between the genera *Ligniera* and *Sorosphaera*.''

W. R. Ivimey Cook and E. J. Schwarts (1929) published a paper (**4**) on a new species, *Sorosphaera radicale* in which they said,—

''This new species seems to indicate that there is a definite relationship between the genus *Sorosphaera* and the genus *Ligniera*, and that hypertrophy is not a feature upon which too much importance must be based. Despite the comparatively close affinity between the two genera, it is a matter of very great difficulty to determine which of the two should be considered the more primitive. If, as has been pointed out before, spore systems are considered more advanced than scattered spores then *Sorosphaera* has been evolved from *Ligniera*.''

Fitzpatrick (1930) (**9**) recognized but five genera: (1) Plasmodiophora, (2) Tetramyxa, (3) Sorosphaera, (4) Sorodiscus and (5) Spongospora. In Plasmodiophora the spores at maturity are not united and are free in the host cells. In Sorosphaera the spores are united into more or less definite spore balls which are spherical to ellipsoidal, hollow and consisting of a peripheral layer of spores enclosing a central cavity. He refused to recognize the genus Ligniera with the following statement,—

''As the genus *Ligniera* Maire & Tison was based merely on a host reaction the writer is wholly disinclined to accept it as valid. It is clear that two hosts may react quite differently to a given parasite, one being stimulated to gall formation, while the other is not. It seems best for the present to include all the species in *Sorosphaera*, even though in some the tendency to form definite spore balls is much less evident than in the type species *S. veronicae* Schröter.''

A recent paper on this subject is the Taxonomy of the Plasmodiophoraceae by Palm and Burk (**14**). Their conclusions are based largely on a species of *Sorosphaera* on *Veronica americana* collected in Colorado. This species showed characters of *Sorosphaera, Sorodiscus, Ligniera, Clathresorus and Spongospora.* As a result of the studies they have suggested that *Spongospora, Ligniera, Sorodiscus, Ostenfoldiolla, Clathresorus* and *Membranosorus* should be made synonyms of *Sorosphaera.* The careful review that they have made of the subject appears to justify their suggestions. The writer is very much in sympathy with the suggestion. The organism under consideration does not fit exactly into any of the genera of Plasmodiophoraceae but it would fit into a genus Sorosphaera made to include the genera as suggested by Palm and Burk. The writer is of the opinion that this organism should be kept in the genus *Ligniera* or that there should be a merging of genera as suggested by Palm and Burk in which it would become *Sorosphaera vascularum.*

Economic Importance

These studies have not given us as much data on this phase of the subject as we expected owing to the fact that we have not had the facilities for pursuing this phase of the work. All of the studies recorded in this paper have been made at the Experiment Station. Our knowledge of this phase of the subject may be summarized as follows,—

(1) It is more severe on some varieties than on others. It was very severe on D–109, a variety which is no longer in use on the island. It stopped the distribution of P. R. 801, a very promising new variety. Our knowledge of its relationship to other varieties is very meager.

A recent outbreak of the disease on first ratoon of FC 1017 showed an infection of about 20 per cent. This cane was growing in irrigated Vega Baja silt loam which is rather difficult to drain and there had been a heavy rainfall over a considerable period of time. The same variety growing in easily drained soil did not show any symptoms of the disease although it is possible that there may have been some infection.

(2) It is most severe in poorly drained soils. A variety that is severely attacked by this organism under these conditions may thrive in well drained soil. The cane growing in low areas in a field may be severely damaged by this fungus while the surrounding cane of

the same variety, but growing on higher land, may appear perfectly healthy. Cane growing on the higher levels may appear to be perfectly healthy but a careful examination may reveal the organism in some of the plants. On at least two occasions we have found that the cane in severely infected plantings was grown from cuttings that came from apparently healthy cane on well drained soil which upon examination showed the organism.

(3) The most important method of distribution from place to place is in the seed cuttings. It undoubtedly travels through wet soil from diseased to healthy plants, probably by zoospores which penetrate the roots.

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Explanation of Figures

1. Transition from plasmodium to spores. Nuclei appear with the formation of spores. (1 *b*).

2. Same. One old spore which did not germinate. The tracheary tube was cut oblique.

3. Cross section of tracheary tube showing formation of spores, one large spore which did not germinate, a spore with there nuclei which may indicate the formation of a quadrate, and surplus protoplasm.

4. Spore formation showing formation of quadrates.

5. Three large spores approaching maturity but both nuclei and inner bodies take the stain.

6. Three large spores kept in distilled water for 24 hours. The contents was moving rapidly, *a.* in one direction, *b.* in the opposite, *c.* showed a cell division and the contents of both halves were moving, *d.* showed three cell, was apparently a quadrate division, but there was no movement of the contents.

7. Germination of the resting spores by the formation of germ tubes and the transition of the zoospores into amoeboid stages.

8. The tracheary tubes and surroundings cells. Note the large spores in the tracheary tubes and in some of the small cells.

9. Two tracheary tubes. Note large spores in one and small spores in the other. Also small spores in small cells.

10. Tracheary tube surrounded by small cells. Note large and small spores in tracheary tube and small spores in surrounding cells.

11. Large and small spores in a tracheary tube.

12. Tracheary tube with large and small spores.

13. Part of tracheary tube and small cells. Both filled with small spores.

14. Two cells among fibrous cells, one with large and one with small spores. Note the thick walls.

15. Three cells among fibrous cells, one with plasmodium and two small spores. Note thick walls.

16. Small cells among fibrous cells, containing large spores. Note thick walls.

17. Three types of spores. The three large spores from one tracheary tube. The small spores of two sizes from another.

18, 19, 20. Large and small spores. Each group from a different tracheary tube.

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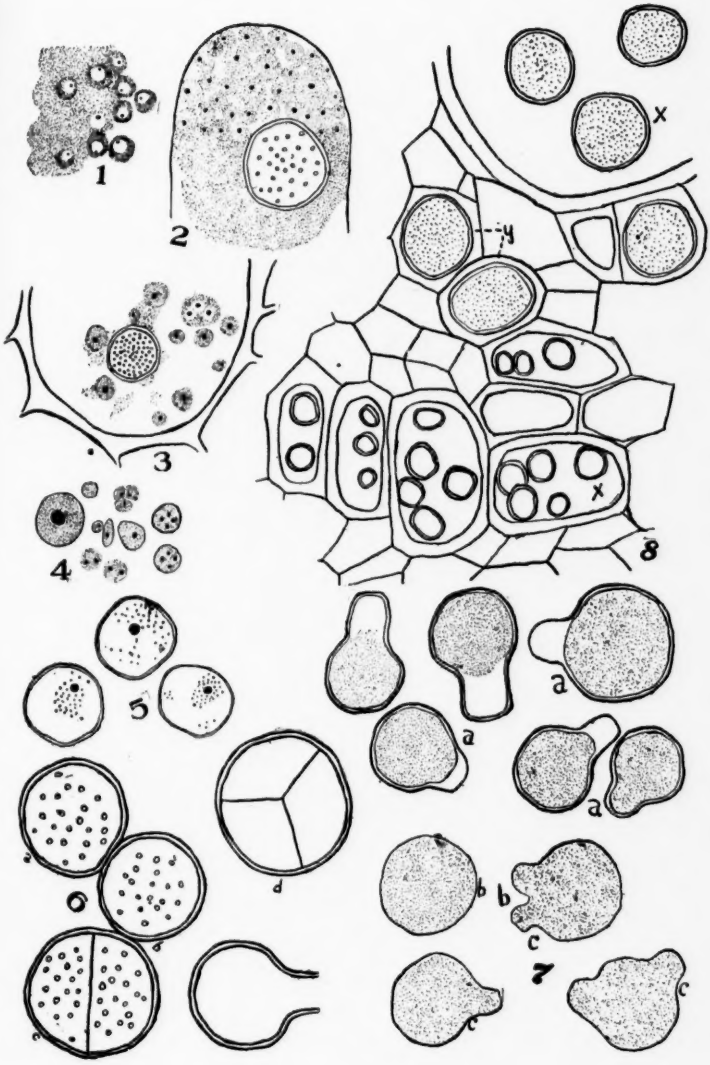
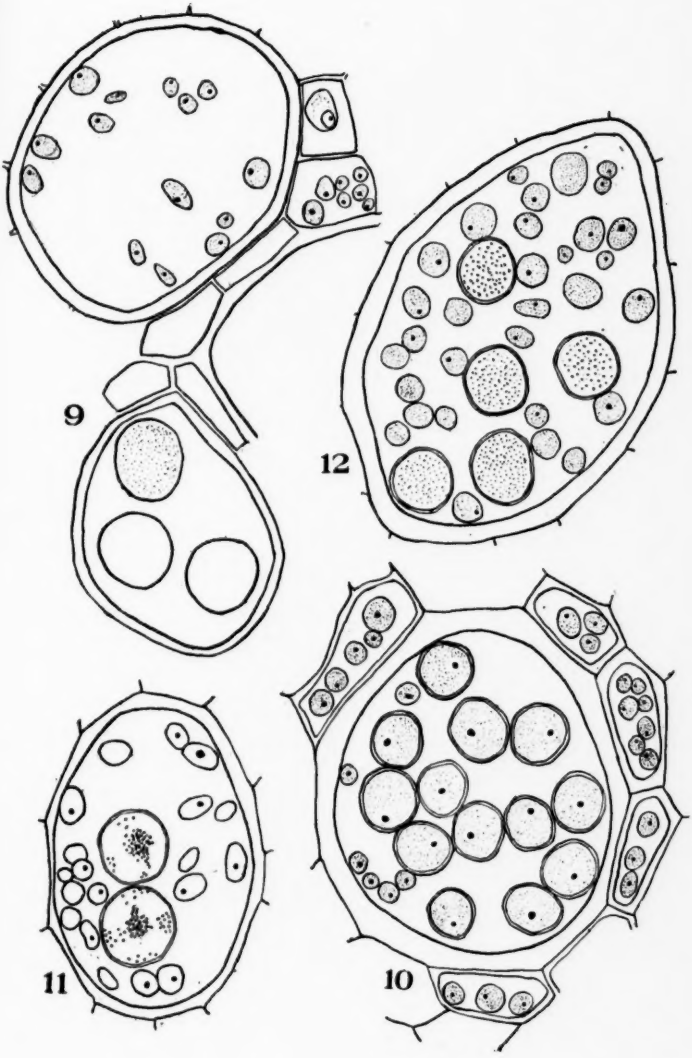
PLATE V





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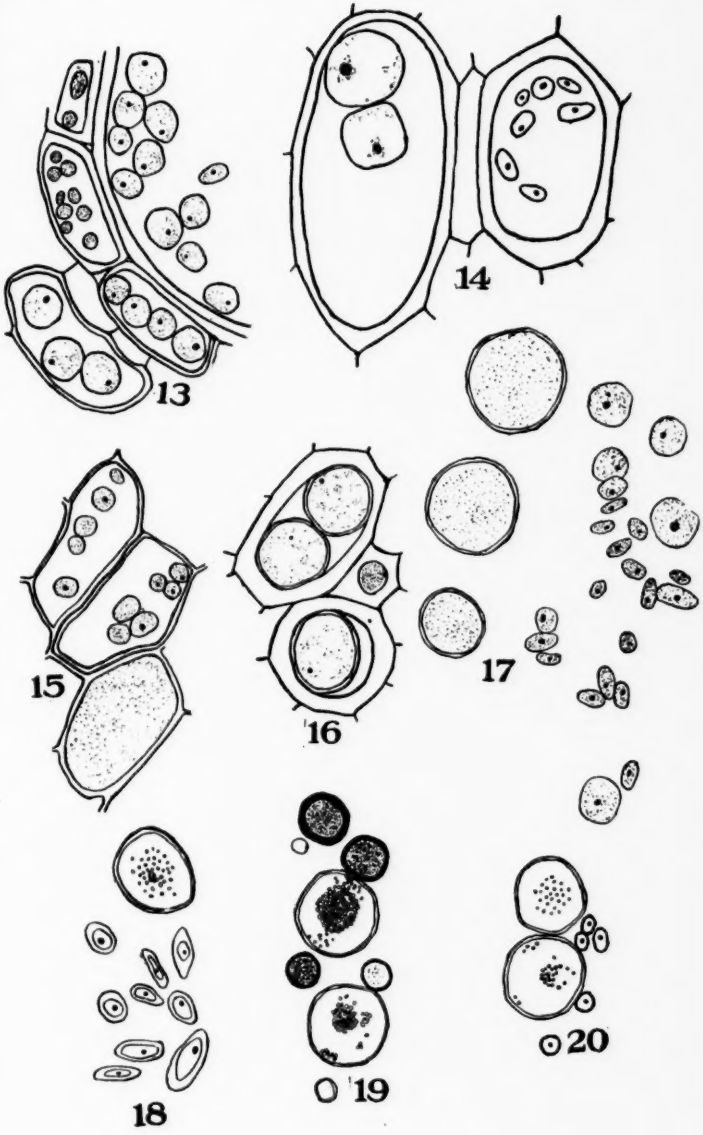
PLATE VII